The heart rate and the muscle activation patterns of trunk and lower limb in different modes of carrying school trolley and backpack

by

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Statement of Originality

I, PANG, Siu Chuen, hereby declare that I am the sole author of the thesis and the material presented in this thesis is my original work except those indicated in the acknowledgement. I further declare that I have followed the University's policies and regulations on Academic Honesty, Copy Right and Plagiarism in writing the thesis and no material in this thesis has been published or submitted for a degree in this or other universities.

Abstract

This study analyzed the heart rate and muscle activation pattern associated with carrying of school trolley and school backpack with different loads. **Methods:** Twenty-five school children which 14 were males and 11 were females was included with a mean age 13.4 (SD = 1.1) year, a mean height of 154.1 (SD = 7.7) cm, and a mean weight of 42.8 (SD = 8.0) kg to walk at a self-selected speed under 24 experimental conditions: 1) carrying a school trolley or 2) carrying a school backpack with 1) 0%, 2) 10%, 3) 15% and 4) 20% of the subject's body weight (BW) during 1) level walking, 2) upstairs walking and 3) downstairs walking respectively. The students performed upstairs and downstairs walking on a thirty-step staircase (stair dimensions of 15.0 cm height and 33.0 cm depth). The subjects completed 30 steps in each condition in a randomize order, and 15 gait cycles were identified in each walking trials. Electromyography data is normalized in terms of the percentage of maximum voluntary contraction (MVC%) from twelve muscles. Averages and standard deviations of heart rate, maximum MVC% and mean MVC% were obtained from both of the left and right sides of tibialis anterior muscle, gastrocnemius muscle, lumbar erector spinae muscle, rectus abdominus muscle, semitendinosus muscle and rectus femoris muscles. The mean heart rate increased significantly with the greater load carriage during the walking trials. No significant difference was found in heart rate response between carrying of school trolley and carrying of school backpack during level walking, upstairs walking, and downstairs walking. Notably, pulling school trolley with load during level walking has less muscle activation in most of the muscles except semitendinosus muscle compared with carrying of school backpack. However, the carry of the school backpack is superior to the school trolley in terms of less muscular activities in twelve muscles during upstairs walking with load carriage. Moreover, carrying the school backpack is superior to the school trolley in terms of less muscular activities in twelve muscles during downstairs walking with load carriage. It is therefore suggested that the school backpack is a more effective carrying method than the school trolley as it minimizes the asymmetrical work in lumbar erector spinae muscle activities during upstairs and downstairs walking. **Conclusions**: Pulling a school trolley with load not more than 20% BW in time of level walking is recommended for school children to carry school necessities. Carrying the school backpack is superior to the school trolley with 10% to 20% BW load carriage in terms of less muscular activities' patterns of trunk and lower limb during upstairs and downstairs walking.

Keywords: Backpack, Surface electromyography, Trolley

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List of Abbreviations

BW	Body Weight
BPM	Beat Per Minute
EMC	Expected Maximum Contraction
MVC	Maximum Voluntary Contraction
RPE	Rating of Perceived Exertion
SEMG	Surface Electromyography

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Chapter 1: Introduction

Overview

Purpose: To analyze the heart rate, the trunk and lower limb muscle activation patterns during different modes of carriage of school trolley and backpack.

Background

Risks of using school backpack

Students have been noticed in carrying school backpack with all the books and supplies for the whole day. Although the long-term effects on the musculoskeletal system are unknown, the repetitive stress of carrying heavy school backpacks may be an important risk factor for the musculoskeletal symptoms that were seen amongst secondary school students. Research found that the school backpacks of 10-15% of body weight (BW) are acceptable limit based on different approaches such as epidemiology, physiology and biomechanics (Al-Khabbaz, Shimada, & Hasegawa, 2008). According to the study done by Malhotra and Sen Gupta in 1965, it recommended that load that is permissible for school children to carry should not be more than 10-12% of their body weight. In his experiment, it was discovered that no subjects bend forward. Subsequently, the above recommendations were applied and accepted for the criterion of the weight of school children carriage. Unfortunately, previous studies had shown that between 4.7%

to 38% of children transport their school backpacks exceed 20% BW in their daily routine. However, it is not clear to have a weight limit in terms of body weight for different stages of students such as child, pre-teen and teenagers. Apart from the weight limit of school backpack, the duration and methods of carrying school backpack and some other factors should be studied to formulate the suitable guidelines for the students. The physical activity level, physical capability and psychological factors are other risk factor as pain or discomfort was reported by the students respectively. It however pointed out that very few studies have investigated the severity of symptoms due to school backpack and school trolley among school children(Dianat, Javadivala, Asghari-Jafarabadi, Asl Hashemi, & Haslegrave, 2013). Therefore, it is critical to figure out the guidelines for the specific age group of school children and their appropriate load carriage methods. Recently, the school trolleys had been used by many students and it became an alternative for the traditional school backpacks as it helped to eliminate the need to support the load on the back.

Benefits from using school trolley

The school trolley helps the students to transport heavier loads during walking with less kinematic adaptations in the ankle, hip, pelvis and thorax when compared with the usage of a traditional school backpack (Orantes-Gonzalez, Heredia-Jimenez, & Beneck, 2016). There was an association between the school backpack and the occurrence of neck and shoulder complaints. Moreover, there was an association between the type of school backpack and the occurrence of lower back complaints (Dianat, Sorkhi, Pourhossein, Alipour, & Asghari-Jafarabadi, 2014). Besides, most of the parents believed that the school trolleys seem to solve the heavy load problem for the secondary students. To compare with carrying the traditional school backpacks, pulling a school trolley is an asymmetric activity. The school children carried the school necessities by pulling the school trolley with loads which are 15.7% BW averagely. The school trolley was about 30% or 2.4kg heavier than a school backpack (Orantes-Gonzalez et al., 2016). A study found that the rate of perceived exertion (RPE) and metabolic costs such as heart rate and maximum oxygen uptake showed a significant decrement. Especially, when the subjects were carrying a two-strap golf bag and clubs compared with when they were carrying the same bag with one strap (Ikeda, Cooper, Gulick, & Nguyen, 2008). Asymmetry in muscle activity may relate to a failure of trunk stabilization and it may cause the contribution of the development of lower back pain (Motmans, Tomlow, & Vissers, 2006).

Interventions for study

Electromyography will be used to provide the information of neural control during different locomotor tasks such as school backpack and trolley carriage (Yali, Aiguo, Haitao, & Songqing, 2015). Most studies applied observation or survey methods to investigate the school backpack related pain syndromes and the majority of the design of the studies were cross-sectional or descriptive one. It may not able to find out convincing evidence to support the effectiveness of the loaded carriage methodology (Adeyemi, Rohani, & Rani, 2015). Interestingly, current studies discovered that loaded school backpack carriage led to the alteration of associated trunk muscle activities and postures. The above biomechanical alteration may cause different musculoskeletal symptoms in the trunk muscles of the school children. It is crucial that to apply different data such as physiological and biomechanical information to investigate the risk of loaded school backpack carriage and to discover any interventions for related injuries preventions (Al-Khabbaz et al., 2008). Note worthily, it has limited study which has investigated the physiological parameters and / or muscle activation pattern of trunk and lower limb when carrying school trolley. Thus, it is highly suggested that physiological parameters such as heart rate is recommended for future research in the related field. In addition, electromyography (EMG) analysis should be considered in analyzing the effect of school trolley carriage on muscle activation pattern.

Current situation

There was a study (Pau, Leban, Paderi, & Nussbaum, 2013) which characterized the pulling forces that was needed during school trolley carriage. Although pulling a trolley can save a lot of muscle force and energy as the load is supported by the ground, however it can only be found in the walking level or mildly inclined ground path walking with trolley. It showed a significant less demand for the school children compared with the school backpack carriage. Nevertheless, there was asymmetric load and large dynamic forces stressed on the body. It required further experimental study and biomechanical test to assess the children posture in carrying the school trolley during the upstairs walking and downstairs walking. A previous research studied the effect of pulling the school trolley with different loads during level walking on the spatiotemporal gait parameters of school children (Orantes-Gonzalez, Heredia-Jimenez, & Soto-Hermoso, 2015). There was no significant difference between different loadings (10%, 15% and 20% BW) in pulling the trolley during level walking. The study only found the significant change in most of the spatiotemporal gait parameters such as cadence, swing phase, stance phase, single support phase and double support phase. These changes are influenced by the asymmetrical load on the body and it caused the changes in the balance or stability (Orantes-Gonzalez, Heredia-Jimenez, & Soto-Hermoso, 2015). Research showed that carrying school bags on one shoulder significantly altered the gait and posture of the youth due to the asymmetrical daily physical stress (Pascoe, Pascoe, Wang, Shim, & Kim, 1997). Moreover, one research showed that the significant greater trunk lean in dynamic conditions than in static conditions. This is because the body is shifted to leaned forward in order to compensate the instability gait during the dynamic conditions. More importantly, the research figured out that 15% BW or greater loads with significant greater trunk lean forward motion during the dynamic movement. It proved that the body applied different strategies to maintain a natural position in balance during static and dynamic conditions respectively (Singh & Koh, 2008). Therefore, it has higher loading stress on the body during level walking compared with the standing position. Lifting heavy weights with back bent forward and trunk bent forward in stooping position were defined as bad postures (Corlett & Bishop, 1976). Pulling a school trolley with optimum load allowed children to maintain walking kinematics which was similar to unloaded walking. Nevertheless, the kinematic parameters were affected asymmetrically by using school trolley. A global conclusion for children about the recommendations in school trolley and school backpack carriage can be formulated by EMG analysis during different walking conditions.

Research aims and objectives

It is worth to note that previous studies had examined the gait kinematic adaptation, gait asymmetry and rating of perceived exertion (RPE) between carrying of a backpack and pulling of a trolley with different loads. The aim of the present study was therefore to investigate the heart rate response, trunk and lower limb muscle activation pattern associated with school backpack and school trolley carriage among secondary school children in Hong Kong. This is of a particular interest as it concerns more different walking conditions such as upstairs walking and downstairs walking than those in most previous studies. It also considered any asymmetrical work of left and right sides of the muscle in carrying school backpack and school trolley with load during level walking, upstairs walking and downstairs walking. The intention was to assist in introducing preventative measures and developing guidelines in relation to the safe load carriage in school backpack and school trolley during level walking, upstairs walking and downstairs walking for school children in Hong Kong and any other nation. The aim of this study was to analyze the heart rate and muscle activation pattern of trunk and lower limb while carrying a school trolley or school backpack with different loads during level, upstairs and downstairs walking in secondary school participants. It was hypothesized that with increasing load, there is as well as increase in the muscle activity and a change in the heart rate. Besides, it was hypothesized that asymmetric lifting school trolley during upstairs and downstairs walking would affect the muscle activation pattern of trunk and lower limb.

The importance of the proposed research

Researchers advised that school children should use the school lockers and minimize the weight of school backpack carriage (Skaggs, Early, D'Ambra, Tolo, & Kay, 2006). This research interviewed 1540 children whose aged were 11-14 years in United States, and discovered that children reported less back pain if they have used the lockers at school. Moreover, the back pain of the school children was associated with the carrying of the heavier school backpack. (Skaggs, Early, D'Ambra, Tolo, & Kay, 2006). It is supported by the other research in Egypt, which showed that 74.1% of the studied subjects had suffered from back pain. In addition, most of the school children carry the school backpack more than the recommended weight (10-15% BW) (Ali El-Nagar, 2017). Hong Kong has the similar situation that school children may not fully utilize the locker at school and they carry the school backpack with many unnecessary items as they have not managed the carriage load of their school backpack. Thus, the present research finding may be useful in advising families to choose school backpack or school trolley under different walking conditions. Moreover, it may influence the school policies, i.e. installation of lockers in different floors, design and apply more pathway for pulling school trolley. Hong Kong is a crowded city with different tunnels and footbridges to connect different buildings and roads. School children may not able to use lift in their schools. They have to carry the school necessities through level walking, upstairs walking and downstairs walking in their daily lives. The outcome of the present study can contribute to the education sector in terms of the safe and health of the school children.

Chapter 2: Literature review

Overview

Different researches investigated the changes in different physiological variables such as heart rate, oxygen consumption, body core temperature, subjective pain feeling as well as different muscle activations such as head, neck, shoulders, trunk and lower body extremity muscles, different gait and biomechanical factors during the loaded backpack carriage in standing or walking interventions. Walking with load carriage required good individual balance and it is related to the shift of center of mass and the base of support (Yen, Ling, Magill, McDonough & Gutierrez, 2011). It's common to find school children carrying loaded school backpack in the daily life, and as such the researchers were interested to study the activity and how does it affect the school children. The first study about the school backpack carriage was held in 1965 and several kinds of systemic literatures' reviews about school backpack carriage including the recommendation of load carriage. However, there was no concluded evidence to prove the 10% BW guideline for the school backpack load carriage. Weight limit of 10-15% BW was rational for the school backpack load carriage due to the demand of physiological need and the effects of biomechanical factors such as the change of posture and gait (Dockrell, Simms, & Blake, 2015). Research showed that numerous school children that carried school backpack exceeded the recommended load which was 10-15% BW and it was related to the high back pain of the school children (Adeyemi, Rohani, & Rani, 2015). Walking activity might add to the stress on the spine repeatedly. Also, walking while carrying the loaded school backpack might add extra loading in the lumbar spine. Nonetheless, a long duration of walking activity with heavy loaded school backpack carriage were considered as one of the risk factors of the lower back problems (Li, Zheng, & Chow, 2019). Statistics showed that over 2.5 million Saudi Arabia school children carried school backpack 5 days per week in the academic year. If the school children carry the school backpack by slinging over one shoulder, it may cause the muscle strain and affect the curve of the natural spine and the round of the shoulder. The school backpack with heavy loading was found to be related to the body pain. If the school children are persisted under the above risk during the academic years, the school children may suffer from by chronic back problem and it may be extended to the stage of adult (Al-Hazzaa, 2006). School backpack carriage by the school children may also be related to the risk of different chronic issues such as back strain, low back pain, poor posture, altered gait and etc. As a result, it alerted the parents in different countries such as United States, Australia, India, Italy, Poland, India, Brazil, Egypt, Hong Kong and etc. The parents and schools have taken different interventions to reduce the risk of different chronic issues. Some of the schools limited the weight of the school backpacks during the school days. Moreover, some of the school advised the students to keep the school backpacks in the students' lockers. Furthermore, school backpack with rollers and the wheeled school backpacks turned out to be the one commonly used in the schools. According to the statistics from a research, the mean of the weight of wheeled school backpack with the necessities was 4.9kg which was heavier than the mean (2.5kg) of the weight of the traditional school backpacks without wheels (Forjuoh, Lane, & Schuchmann, 2003). The characteristics of the school backpack are one of the biomechanical factors which often found in the cause of back pain in children and adolescents. Although there was no convincing evidence to show the relationship between the back pain and the carriage of school backpacks, the back pain problems of children and adolescents always link to the carriage of the school backpacks. It is important to get the advice from the clinicians due to the concerns and awareness from the parents and the school children, so that the general public can understand how to reduce the risk of back pain by the preference style of school backpacks and proper way for the carriage of the school backpacks. According to the results in one systemic review, there was however no convincing evidence to support that the usage of school backpacks increased the risk of back pain. But, some evidences to support the back pain was found to be associated with the perception of heaviness of the school backpack (Yamato, Maher, Traeger, Wiliams, & Kamper, 2018). The researchers found that the duration of carriage of the school backpack was strongly associated with the back pain when compared with the other factors (Al-Hazzaa, 2006). Besides, most of the school children carried their school backpack for 10 min or less from their residence to the school. Apart from that, the perception of school backpack weight from school children was found to be a psychosocial aspect of school backpack related pain (Dockrell, Simms, & Blake, 2015)

The guidelines for school backpack carriage

According to the guidelines from the Australia government and Europe, it claimed that school children are able to carry a school backpack which is 10% of their BW. The above guidelines are similar as the one in United States authorities. For the instance, The American Occupational Therapy Association suggested that 10% BW is the upper limit weight of the school backpack (American Occupational Therapy Association, 2020). In addition, The American Academy of Pediatrics suggested that 10-20% BW is the acceptable range of weight of the school backpack (The American Academy of Pediatrics, 2015). Besides, The American Physical Therapy Association recommended 10-15% BW as the weight range of school backpack (Dockrell et al., 2017). Research suggested that reduction of backpack mass was one of the precautions for the injuries from loaded carrying activity and it helped to change the biomechanical, physiological and psychological factor during the loaded carrying activities (Simpson, Munro, & Steele, 2011). According to a Hong Kong study from Hong Kong Society for Child Health and Development, Hong Kong students carried the school backpack about 20% of BW. It was harder for the school children to initiate a motion if they carry an increased mass of a loaded school backpack. It required rotation on knee and hip to control the walking motion. Back problems or other lower limb overuse injuries were the common musculoskeletal injuries found in the load carriage activities due to the change of gait parameters and postural control patterns (Ketko, Plotnik, Yanovich, Gefen & Heled, 2017). Research found that trunk flexion increment was found in the subjects when they were carrying the school backpack with the loads between 15% to 20% of BW. Furthermore, thorax flexion was found in the subjects when the subjects were carrying an extra load on their back. Apart from trunk flexion and thorax flexion, anterior pelvis tilt trend increment was found in the subjects when they were carrying the load from 15% to 20% BW (Orantess-Gonzalez, Heredia-Jimenez, & Robinson, 2019). Notably, there are different factors associated with the risk of school children's low back pain that includes body weight, strength of the muscle, the load of weight carrying, ergonomics setting, physical activity level, sports participation and etc. Low back pain and shoulder back pain due to school backpack carriage are commonly found in the secondary school students. Research found that more than 80% of school children complained that the excessive loading of their school backpack caused their low back pain. One systematic review found that the data analysis did not support the association between the low back pain and the carrying of more than 10% of BW school backpack in school children aged 9-16 group (Calvo-Muñoz, Kovacs, Roqué, & Seco-Calvo, 2019). The definition of the low back pain is that the pain occurred between the inferior gluteal folds and the costal margin. It usually has painful sensation on the leg with limited movement. It may have change in muscle activation and posture or gait deviations during the loaded school backpack carriage walking. One research found that there was an increased deviation in head posture and angle during the loaded school backpack carriage walking. It is therefore suggested that a modified double backpack should be used by school children in order to reduce the posture deviation (Kim, Yi, Kwon, Cho, & Yoo, 2008). According to the findings from Li & Chow, 2016, the recommendations for the carriage load of school backpack should be 13% BW for healthy male college students. But this study is limited for the male subjects only. Further studies should involve female subjects to establish the guidelines on the load carriage of school backpack. There is difference in the guidelines between obese children and the other children due to the difference in the physical capacity and fitness level. One study suggested that obese children should carry a one-third liger load than other healthy children (Adeyemi, Rohani, & Abdul Rani, 2017). According to different guidelines from local and overseas countries, it is suggested to limit the load carriage below 20%BW of the school children for the health and safety issues.

A suitable position of the school backpack was suggested to distribute the majority of the loading on the hip by tightening the hip strap. The support of the hip belt relieved the stress on the lower back and shoulders as the load was transferred from the shoulders to the waist. It acted as a load distribution device on the trunk and it eased the effect of load carriage (Ketko, Plotnik, Yanovich, Gefen, & Heled, 2017). Meanwhile, the school children were advised to keep the school backpacks closed to their back. In fact, the school children should carry the school backpack with suitable size as heavy and oversized school backpack may cause the school children to have extra strain on their shoulders and back. Physical activity such as walking was beneficial to the school children due to the contribution of energy expenditure and energy balance in their daily lives. Walking with heavy school backpack could provide a tremendous strain on (Yamato, Maher, Traeger, Wiliams, & Kamper, 2018) the child's spine and back muscles (Al-Hazzaa, 2006). It is realized that school backpack carriage is one of the types of physical activities. Therefore, school children should have some positive health advantages from it. Unfortunately, research found that no parents from United States and few parents from Irish recognized school backpack carrying as a kind of exercise which promotes health benefits to the school children (Dockrell et al., 2017). Furthermore, research found that it limited the level of physical activity if the school children did not carry the school backpack. It inhibited the opportunity of having daily resistance training exercise as the school children carried the school backpack every school day. Loaded school backpack carriage could be considered as school children regular physical activity and it was associated with the improvement of physiological and psychological health for school children (Dockrell, Simms, & Blake, 2015). School backpack with load carriage was one of the opportunities for the school children to enhance the level of physical activity. The parents and teachers should ensure the school children carry the loaded school backpack with good positioning in order to reduce the risk of injury.

Factors associated with pain, discomfort and injury for school backpack carriage

One of the risk factors of injury was the weight of the school backpacks. Research demonstrated that the children had back pain if they carry heavier school bags when compared with those children who carried relative light school bag without back pain. Another finding showed that 55% of all subjects had a history of carrying more than 15% of their BWs load. 33% of them reported to have experienced back pain (Goodgold et al., 2002). There were about 79.1% of children reported that they felt the school backpacks were heavy. Research investigated the perceived feeling of the school children; and there were about 65.7% of school children reported that the school backpacks caused fatigue. Furthermore, there was about 46.1% of school children reported that the school backpack actually caused back pain (Negrini & Carabalona, 2002). It is very often to find school children carrying the school backpack that is more than 10% of their BWs during the school days (De Paula, A. J. F., Silva, Paschoarelli, & Fujii, 2012). The school children have to carry 5 days per week in the school term. This chronic stress on their body increased the risk of injury in relation to the heavy weight (Mackie, Legg, Beadle, & Hedderley, 2003).One research finding showed that the increasing loading of school backpack reduced the cadence and speed of walking of the subjects. Meanwhile, the power and the moment at lower limbs such as ankle, knee and hip increased with the loading of the school backpack(Chow et al., 2005). However, there are no conclusion for the relationship between back pain and the loading of school backpack from the research findings. A recent pilot study found that no association between the use of backpack and low back pain in pre-university students in Malaysia (Amyra Natasha, Ahmad Syukri, Siti Nor Diana, M. K., Ima-Nirwana, & Chin, 2018). One observational study supported the perceived school backpack load, and the duration of carriage and methods of transportation commute to the school were associated with the neck pain and back pain among the school children. Luckily, it can minimize the pain if the school children had sufficient physical activity in their daily lives (Haselgrove et al., 2008). A lot of researches investigated the risk factors which are associated with the pain, discomfort and injury from the school backpack carriage. It is crucial that the school children should manage the load carriage of the school backpack i.e. removal of unnecessary stationeries, books and etc.

The effect of the position of the backpack on individuals

Misuse of school backpack may lead to back pain according to the information from American Chiropractic Association. More complaints about back and shoulder discomfort or pain are found from the school children. Different parties such as parents, teachers and other professionals realized that the presence of the discomfort and pain is as a result of the carrying of the loaded school backpacks (American Chiropractic Association, 2021). There are different recommendations for the position of the school backpack carriage. Some however suggested that school children should wear the school backpack on the back at a higher level with tightening shoulder strap. Moreover, there are recommendations from the literature in relation to the correct way for school backpack carriage. There are two common carrying ways for school children to wear the school backpack on one of the shoulders or both of the shoulders(Negrini & Carabalona, 2002).There are differences in the metabolism cost of body between upper and lower position wearing of the school backpack. Research showed that the metabolism cost is higher if the school children wear the school backpack on the upper part of the back. It is suggested that school children should carry the school backpack on two shoulders rather than carrying by one shoulder or by hand. It is more efficient in terms of lower metabolism cost when school children carry the backpack on two shoulders. Research demonstrated that it is more demanding for school children to carry the school backpack by one hand compared with backpack over one shoulder (Kellis & Arampatzi, 2009). There are different positionings of school backpack used by the school children. Forward leaning was found when the school backpack positioned at the highest point on the spine. Research found that greater pressure from the shoulder strap on the subjects if the school backpack is placed higher on the back. Therefore, there are different effects on the school children when they carry different type of school backpack or when they carry the school backpack in different ways (Mackie, Stevenson, Reid, & Legg, 2005). One research showed that the carry of school backpack has significantly higher potential in the risk of falls in terms of the sway parameter among the Italian school children (Pau, M. & Pau, 2010). It is important that the school children should use the school backpack properly regarding the type and the carry way of it.

Study showed that a better maintenance of center of mass can be achieved when the load is placed closer to the body. And this is because the proper recruitment of the major muscle groups such as back and shoulder can facilitate the work of balance. It may use smaller muscle groups such as arm and hand if the load is placed far from the core of the body. This may cause extra demanding on cardiorespiratory and muscular system to compensate the requirement of balance and support of the smaller muscle groups (Chatterjee, Chatterjee, Bhattacharyya, Sen, & Pal, 2018). The positioning of the school backpack may cause pain or discomfort to the school children due to the differences of the muscle recruitment and metabolism cost. It is recommended that the students should carry the loaded school backpack in an optimum position during walking.

The discomfort and pain symptoms associated with school backpack carriage in different genders

Research showed that the risk of non-specific low back pain of female has significant different from the one of male. Female children have higher risk of having low back pain than male children (Frykman, Harman, Knaplk, & Han, 1994). The gender difference is related to the difference of the strength performance. However, it is only applied to the puberty stage instead of prepubertal stage (Kellis & Arampatzi, 2009).

Another research reported that girls were more prone to have low back pain. Also, there were specific association between the age, gender and low back pain (Grimmer & Williams, 2000). There was gender difference on the risk of injury; a lot of girls had back pain than the boys as the boys had stronger physique compared with the girls. School children who carried the heavier backpack had higher risk (about 50%) of back pain. In addition, they had higher risk (about 42%) of back pathology such as muscle strains, ligament sprains and etc (Rodríguez-Oviedo et al., 2012). One research finding did not support the gender difference on the effect of school backpack carriage. One study found that girls were prone to have upper and lower back symptoms than boys among school children. But boys have significant higher severity of low back symptoms than girls (Dianat et al., 2013). One study reported that there was a high incidence of back pain among female school children in Egypt and it proved that the weight of school backpack and the carrying methods have association with the back pain of the female school children (Ibrahim, 2012). There are gender differences in the effect of pain and discomfort in relation to the loaded school backpack carriage due to the strength difference between two genders. It is significant to find out the difference of the muscle activation pattern of the trunk and lower limb during level, upstairs and downstairs walking.

Muscle activity of trunk and lower body extremity during unloaded and different loaded school backpack carriage

Research found that no significant changes in bilateral erector spinae's muscle activities in unloaded standing mode. There were significant changes in bilateral rectus abdominis in unloaded and different loaded standing such as 10%, 15% and 20% loaded modes. More muscle activities were found in the right rectus abdominis compared with the muscle activities in the left rectus abdominis during all of the unloaded and different loaded standing modes. Especially, the rectus abdominis muscle activities significantly increased when the load of school backpack increased. Motion analysis system (VICON 250) was applied to investigate the change in trunk postures such as inclination, side rotation and flexion. The reflective skin markers were attached on several bony markers which were sacrum, elbow lateral epicondyle, radius styloid process, acromion process, 1/3 of the line between the femur greater trochanter lateral side of knee joint and the anterior superior iliac spine, forefoot and calcaneus. The trunk postures included forward inclination; right rotation and right side flexion were changed in all of the loaded standing modes. Previous research found that there exist a higher muscle activity on both of left and right sides of the rectus abdominis muscle during standing status in carrying backpack. It had notable difference between left and right sides of the rectus abdominis muscle EMG MVC% during standing status in carrying shoulder bag and backpack (Motmans, Tomlow, & Vissers, 2006). There were significant changes in trunk inclination during 10%, 15% and 20% BW loaded standing modes. However, no significant changes were found in other trunk postures included trunk side flexion and rotation. Previous study showed no significant change in the lumbar erector spinae muscle EMG MVC% with (10-20% BW) load carriage during standing status in carrying backpack. On the other hand, study showed significant increase in the rectus abdominis muscle EMG MVC% with load carriage (10-20% BW) during standing status in carrying backpack (Al-Khabbaz, Shimada, & Hasegawa, 2008). Previous research found that significant lower muscle activity on both of left and right sides of the lumbar erector spinae muscle during standing status in carrying backpack. Moreover, both of left and right sides of the lumbar erector spinae muscle showed symmetry EMG MVC% (Motmans, Tomlow, & Vissers, 2006). Research found that the central nervous system is essential to stabilize the spine by the contraction of the rectus abdominis, transversus abdominis and multifidus muscles and the coordination of the limb movement(Hodges & Richardson, 1997). Walking is a suggested physical daily activity for the health of individuals. Walking with school backpack and school trolley is currently found in most of the school children. The school children have to carry a lot of textbooks to school daily, and walking with a loaded school backpack over the limitations of the recommendation may cause different kinds of back problems. Research investigated the change of trunk muscle activity and compression force at lumbosacral joint during walking between no load, 5%, 10%, 15% and 20% BW loaded school backpack carriage. The data of muscle activities of the trunk were collected by the wireless surface EMG system. Moreover, the reflective markers were attached to the subjects' lower body during the data collection. However, the lower body movements of the subjects were recorded by the eight Oqus 700+ cameras and force platforms were applied to measure the ground reaction forces during the process. The subjects were required to stand in bare foot on the force platforms in an erect stance comfortably. The subjects were instructed to carry no load, 5%, 10%, 15% and 20% BW loaded school backpack and start 10-meter walk with his preferred speed. The subjects could take one to two minutes' rest between each experiment trials. The subjects could take 5 minutes after they completed a set of walking test. The findings showed that there was a significant change in both of trunk muscle activities and joint forces when the college students were carrying a 10% BW double strap school backpack (Li & Chow, 2017). Trunk muscles are important to stabilize the spine and the trunk muscle coactivity reflects the lumbar spinal protection mechanisms. There is difference between healthy individual and spine injured individual in terms of the spine stabilization(Gagnon, Larivière, & Loisel, 2001). Thus, the muscle activation pattern of the lumbar muscles will perform differently. The changes of lumbosacral joint compression force during walking with loaded backpacks were investigated by current study. Motion analysis, surface EMG and force platform systems were used to analyze the lower body movements, trunk muscle activities and ground reaction forces. There were ten healthy undergraduates which were recruited in the study. The subjects were required to stand in bare foot on the force platforms in an erect stance comfortably. The subjects were instructed to carry no load of 5%, 10%, 15% and 20% BW loaded school backpack and start a 10-meter walk with their preferred speed. The research found that there were no significant changes in the timing of the two peak force profiles. However, the study confirmed a strong relationship between the force profiles at 5%, 10%, 15% and. 20% BW backpack loads (Li et al., 2019). Apart from the effect on the undergraduates that carry loaded backpack while walking, research found that the school children were affected by the loaded backpack carriage. 60 school children aged 7 to 12 years were recruited in the study to investigate the interaction of the muscle activation in different ages and body mass index during the loaded backpack carriage walking. The subjects were instructed to carry four different loads of backpacks which included no load, 5%, 10%, 15%, and 15% BW respectively. EMG signals were analyzed to show the differences of the muscle activations in back and trapezius muscle in different loads of backpack carriage. Borg scale was ranged from zero to ten which represent from no pain to very serious pain for the subjective feelings of the subjects. It was used to show the relationship of pain to work intensity during the loaded backpack carriage. The research found that there was a significant difference in the muscular activities of back and trapezius muscles in different loads of backpack carriage. There was also a significant difference in the pain rating of Borg scale in different loads of backpack carriage. The study concluded that the school children should not have the same recommended weight limits for the school backpack (Adeyemi, Rohani, & Rani, 2015). The effect of loaded school backpack carriage on the muscle activation pattern and subjective feeling is significant. The school trolley should be considered to be a good option for use in the transportation of school necessities.

Gait and biomechanics in loaded carriage during level walking

It is indicated that the pressure and force under different foot regions was higher with heavier load carriage. Besides, one study showed that the gait biomechanics of children which included both of pressure under pressure and stride kinematics was affected by the load carriage by school backpack (Ahmad & Barbosa, 2019). Besides, there was significant increment in plantar pressure during static standing and walking with 5.2kg school backpack carriage (Pau, Massimiliano, Mandaresu, Leban, & Nussbaum, 2014). It alerted parents and teachers about the possible adverse consequences in relation to the use of school backpack. Apart from short term effect of school backpack carriage on plantar pressure and gait of school children, school children always spend a lot of time on carrying school backpack with loading. Another finding showed a weak relationship between school children and school backpack carriage with static pronated feet not developing a neutral foot posture within a period of 36 months (Alfageme-García et al., 2021). Thus, the policy makers and educational practitioners should consider the use of school backpack with heavy loading. One research investigated the biomechanical stresses such as stride, temporal parameters, trunk lean angles, trunk motion range with load carriage during level walking. There was significant difference in the trunk posture in carrying 15% to 20% BW during level walking. The research suggested that the pain and discomfort of muscle can be minimized by taking the precautions of the back postural deviation especially when the backpack load carriage exceeds 15% BW. Moreover, the research suggested that the walking distance with load carriage is another factor to be considered for the school children (Hong, Y. & Cheung, 2003). It is more beneficial for people to use wheeled support devices for loaded carriage. For instance, soldiers always carry heavy loaded backpack in their training or different tasking. It is important to find a more effective way to carry the loaded backpack in order to reduce the related injuries and improve the effectiveness of the daily physical activities. Current study found that wheeled assistive devices were able to reduce the load on the soldiers because of the potential biomechanical advantages. Thirteen healthy male subjects were examined in the study and they were required to carry different loads in the experiment. They had to carry no load, military backpack with 40% BW load and with the wheeled assistive devices to carry military backpack with 40% BW load. They had to complete four trials in 10 minutes walking with the above different loaded carriage at different speeds and inclinations on a treadmill. The treadmill was installed with an electronic mat and force sensors to collect the data of vertical ground reaction forces. Furthermore, the customized Tactillus pressure mapping mat was used in the backpack strap to collect the data of contact pressure which acted on the shoulder of the subjects. The biomechanical analysis proved that the wheeled assistive device reduced the vertical ground reaction force in the treadmill walking test and contact pressure on the subjects' shoulders. Meanwhile, the study suggested that the ergonomics design of wheel assistive device should be adjusted to improve the control of balance and the gait in the future (Ketko, Plotnik, Yanovich, Gefen & Heled, 2017). Research also found the influence of carrying a backpack on other parameters. Notably, it had significant less range of motion in pelvic obliquity and rotation in carrying school backpack during level walking with 15% BW load

(Smith et al., 2006). One research recruited fifty-three school children which included 24 males and 29 females to conduct an experiment to compare the effect between pulling the school trolley and school backpack (Orantes-Gonzalez, Heredia-Jimenez, & Beneck, 2016). The subjects had to complete the experiment in different conditions: walking 15 meters with carrying the 15% BW loaded school backpack and pulling the school trolley in randomized order with their preferred speed. The kinematics of gait was analyzed a 3D motion capture system with the infrared speed cameras and reflective markers. The results showed that subjects had significant greater hip, pelvic, thorax flexion, hip adduction and internal rotation. It supported that pulling the school trolley may cause harm to the skeletal muscles and associated joints when comparing with the carrying in the school backpack during stairs or ramps walking conditions. However, it is recommended to use the school trolley during the standing activities compared with the carrying of the school backpack due to less musculoskeletal injuries' risk and less adaptation in the lower body joints such as thorax, hip, pelvis and ankles. Therefore, it is recommended the school children should use school trolley with 15% BW or less load during the level walking. It found that the future study should involve more challenging daily tasks such as walking stairs or steps with carrying the school trolley. Meanwhile, 15% BW is less than the daily life practice as school children always carry heavier load in the real situation. Thus, carrying the school backpack and the school trolley with heavier load such as 20% BW is suggested to be used in the future experiment. Previous study (Orantes-Gonzalez & Heredia-Jimenez, 2017)recruited fifty-three school children which included 25 males and 28 females to conduct an experiment in relation to walking 15 meters with 10%, 15%, 20% BW loaded or unloaded school trolley in randomized order with their preferred speeds. The kinematics of lower limbs, thorax and gait were analyzed a 3D motion capture system with the high speed cameras and reflective markers. The subjects completed a familiarization phase before four different experimental conditions. The thorax part of the subjects reflected the main effect of the school trolley loads. But there was no interaction between the types of carrying methods i.e. school trolleys / school backpack and the kinematic parameters. It indicated that school backpack users were not required to have adaptation on the similar kinematic factors as the school trolley users. The asymmetrical task in carrying the school trolley affected the transverse plane of the thorax majority. The carrying weight of the school trolley caused the kinematic change on the sagittal plane of the pelvis and thorax. It showed that the greater flexion in pelvis is found with higher loaded of school trolley pulling. It is suggested that an EMG data analysis for the trunk muscles should be implemented to draw a more comprehensive recommendation for the school trolley and school backpack user guide.

Gait and biomechanics in loaded carriage during upstairs and downstairs walking

It is more demanding in upstairs walking than in level walking. Research found that the flexion moment of the knee during upstairs walking is significantly higher than level walking. The peak patella-femoral contact force of upstairs walking is 8 times higher than in level walking (Costigan, Deluzio, & Wyss, 2002). It is therefore important to examine the muscle activation in different walking condition such as upstairs walking, as a result of the difference between level walking and stairs climbing. In most of the school setting in Hong Kong, school children have to climb the stairs up and down in carrying the school backpack. One research analyzed the insole pressure during upstairs and downstairs walking with load carriage. It found that peak force increased significantly with 15% BW carriage during upstairs walking (Hong, Y. & Li, 2005). It may have influence on the muscle activation pattern of trunk and lower limbs during upstairs and downstairs walking when there are no presence of lift or escalator in the school campus. The school children have to lift the school trolley asymmetrically during upstairs and downstairs walking.

Physiological variables (Heart rate, oxygen consumption, body core temperature, subjective comfort rating) in load carriage

Research found that the students showed significant increment of heart rate and Borg scores when they carried the heavier load of school backpack. 20 healthy college students were recruited in the study and they were instructed to carry four different loaded backpack which included 0%, 5%, 10%, 15% of BW in one standing and one 5 minutes walking conditions. According to the significant change in Borg scores, data of kinematics and EMG with 15% and 20% of BW loaded. Regarding school backpack, the result supported that the students should carry a school backpack 10% of BW or less in the daily life(Devroey, Jonkers, de Becker, Lenaerts, & Spaepen, 2007). One study compared the difference in the metabolic cost between single and double strap golf bag, and it was observed to show the difference in different carriage interventions. Fifteen healthy men were recruited in the study and had to complete a five-minute treadmill walking test with single and double strap loaded golf bad carriage. It proved that single strap golf bag carriage required higher demand on the cardiorespiratory system which proved the significant change in the perceived discomfort, perceived exertion, heart rate and oxygen consumption (Ikeda et al., 2008). Current study investigated the physiological changes in loaded backpack carriage walking. It found no significant differences in the physiological variables such as heart rate, body core temperature, oxygen consumption and subjective comfort when the subjects carried the loaded backpack and loaded backpack with wheeled assistive device during the treadmill walking test. Ten healthy male subjects were invited in the study and they were required to carry different loads in the experiment. They had to carry no load, military backpack with 40% BW load and with the wheeled assistive devices to carry military backpack with 40% BW load. They had to complete four trials in 10 minutes walking with the above different loaded carriage at different speeds and inclinations on a treadmill. Oxygen consumption was measured by the setting of cardio pulmonary exercise testing protocol. Moreover, heart rate was measured by Polar RS800 heart rate monitor and body core temperature were measured by a rectal thermistor and monitored by the tele-thermometer during the test. Besides, rate of perceived exertion was used to be rate of subjective comfort of the subjects from very easy to very difficult in the BORG scale from 6 to 20. The study found that the subjects felt they were more comfortable when they conducted the treadmill walking test with the wheeled assistive device. However, it showed the difficulties in controlling the balance during the treadmill walking test with the wheeled assistive device (Ketko, Yanovich, Plotnik, Gefen, & Heled, 2015). The recent publication showed that the overweight or obese school children had a lower rate of perceived exertion (RPE) in pulling the school trolley with 10% and 15% BW load when compared with healthy weight school children. The study recruited forty-eight students and they had to carry the school backpack with 10%, 15%, 20% BW and pulling the school trolley with 10%, 15%, 20% BW in the 15 meters walking test. The study suggested that heart rate should be applied to be a physiological variable measurement in the future investigation for the effect of school backpack carriage and school trolley pulling (Orantes-Gonzalez & Heredia-Jimenez, 2021). Overweight children adopted a significant different gait compared with the underweight children during walking as the overweight children showed significant greater duration in lower extremity muscle activity i.e. vastus lateralis and gastrocnemius muscles (Blakemore, Fink, Lark,& Shultz, 2013). It is essential to find out an effective way for school children to carry the school necessities as there are significant demanding on their cardiovascular and musculoskeletal system during loaded carriage walking.

Application of surface electromyography (SEMG)

Myo-electric activity evaluation required frequency analysis. EMG potential can be stated as number of phases, amplitude and duration at relative lower muscle contraction levels. This is an essential tool to evaluate the muscle activation with normalization (Marras, W. S., Davis, & Maronitis, 2001). One of the reasons of muscle fatigue is caused by a sustained forceful muscle contraction (Lindstrom, Magnusson, & Petersén, 1970). The data from EMG represent the muscle activation. There is a linear relationship between the muscle tension and EMG during isometric muscle contraction(Sutherland, 2001). EMG is one of the important tools for the clinical gait analysis. The reliability of the EMG data may vary in the respective walking speed during the dynamic movement (Hershler & Milner, 1978). Therefore, walking speed is one of the factors which affect the result of muscle activation pattern. There are differences in the muscle activation between healthy individuals and the chronic low back patients. The chronic low back pain patients showed weaker and fatigued faster in terms of the muscle activation in lumbar paraspinal muscles and gluteus maximus muscles (Kankaanpää, Taimela, Laaksonen, Hänninen, & Airaksinen, 1998).

Pressure sensitive foot switches can combine with the EMG system to identify the gait cycle and the relationship with the muscular system. Foot switches detect the pressure of foot in each step by identification of a load on or off from the foot. The gait cycles can be identified by the pressure detection in each step after the data processing from the foot switches. However, the installation of the foot switches inside the shoes required the application of additional equipment. It limited some populations which have abnormal gait to use the foot switches. Researcher can also consider to use the force plate together with the foot switch to acquire more information during the data collection (Zeni, Jr, & Higginson, 2007). Surface EMG is one of the important tools to analyze the clinical gait as it can identify the muscle activation information of the superficial muscles during dynamic movement. Previous study has investigated the effect of electrode location on EMG signal envelope in lower limb muscles during dynamic movement. The investigated lower limbs muscles included tibialis anterior, gastrocnemius medialis, gastrocnemius laterialis, soleus and peroneus longus muscles. This is because the surface EMG is affected by the difference of the electrode locations in different sessions of the experiment. There are some factors which affect the estimation of the muscle activation by the EMG such as the change of joint angles and submaximal contraction during the gait. The recommendations for the electrode locations on different muscles during the static contractions can be found in the European project Surface Electromyography for Non-Invasive Muscle Assessment. Apart from the location of the electrodes on the measured muscles, the noise and impedance of skin-electrodes are other factors which may have influence on the estimate of the intensity of muscle activations. It is important to treat the skin of muscles by abrasive paste properly (Campanini et al., 2006). Besides, the area and the shape of electrodes (Burden & Bartlett, 1999), motor unit and muscle fiber types properties, skin perspiration and temperature(Hsu, Krishnamoorthy, & Scholz, 2006)may affect the frequency and amplitude of the raw EMG data. High quality recording of EMG can ensure the accuracy of the result of muscle activation pattern. Therefore, it is essential to maintain standardization of EMG instrumentation in the experiment. Self-adhesive, disposable surface electrodes are used for recording the surface EMG data. These are the silver-silver chloride electrodes and it can be used several times on the same subject. There are some limitations for the EMG recording system to get the exact reproduction of the physiological signals from the muscle. Artefact from technical and biological origin is unavoidable. The source of the artefact from technical origin included cable motion artefact, skin stretch, high electrode skin electrode impedance, noise from the EMG machine and other biomedical devices such as pacemaker. The source of the artefact from biological origin included electrocardiogram, and the biological crosstalk between neighboring muscles (Tankisi et al., 2020).

Normalization of EMG raw data

There are different methods to normalize the frequency and amplitude of EMG raw data such as single isometric maximal voluntary contraction method, submaximal voluntary contraction method, ten isokinetic maximal voluntary contraction method, dynamic mean method, dynamic peak method, arbitrary angle isometric maximal non-isometric voluntary contraction, angle specific maximal isometric voluntary contraction, angle specific maximal dynamic voluntary contraction, angle and angular velocity specific maximal isokinetic voluntary contraction (Burden, 2010).There was however an alternative EMG normalization method which is called torque-velocity test for lower limb muscle activation during submaximal cycling test (Rouffet & Hautier, 2007). Furthermore, one study investigated the MVC, sprint and 70% peak running speed method during running activity. It showed that the dynamic normalization methods were the most repeatable and appropriate one to apply in the running activity (Albertus-Kajee, Tucker, Derman, Lamberts, & Lambert, 2011). It is important to conduct normalization for EMG signals to minimize the errors in the interpretation of the EMG raw data. Researchers especially need to do the comparisons between different trials, muscles or individual in the study. It enables the comparison of the result between individual subjects and analysis of muscle activation been useful in the research related to ergonomics, sports science, medicine and rehabilitation (Kukla, Wieczorek, & Warguła, 2018). Normalization of EMG data from healthy individuals can enable the researchers to examine the percentage of the muscle activation. Research found that there was discrepancy between the normalized and unnormalized EMG data of the upper and lower rectus abdominis muscles due to the inherent signal variability. It is suggested that normalization can reduce the error of the physiological interpretation of EMG signals (Lehman & McGill, 1999). Maximum voluntary isometric contraction test evaluates the muscle group in a specific position to perform maximal force as fast as possible and maintain for at least 3 seconds. However, the traditional MVIC test requires the subjects to perform the test in at least five different positions such as sitting, supine, prone and etc. It is quite time consuming for the researcher and energy consuming for the subjects (Hsu, Kristnamoorthy, & Scholz, 2006), if the individuals are unable to provide a MVC i.e. injury on the specific joints and muscles. The estimation of the expected maximum contraction (EMC) and sub-maximal exertions is a reference value that can be used in normalization. Maximum exertion is not required in the EMC and it can assess the EMG signals from the special population (Marras et al., 2001). There is difference between EMG in low back pain patient and normal individual. Research found that low back patient showed higher EMG value during endurance isometric contraction and it may be due to the fatiguing erector spinae muscle (Tsuboi, Satou, Egawa, Izumi, & Miyazaki, 1994). One study supported that several MVIC positions is recommended to normalize the EMG data of gastrocnemius muscle. But the researcher has to consider the real situation of the subjects as some patients may be limited by too many MVIC attempts. Therefore, one single position of MVIC should be applied in the experiment (Schwartz et al., 2020). There is a need to investigate the impact of school trolley carriage and school trolley mass on muscle activation pattern of trunk and lower limb. It is common to see school parent will choose school trolley for their children. Besides, low back pain remains an essential health issue in most countries. Lifting load has long been associated with the risk of low back pain. One of the risk factors is an unbalanced load during lifting (Ramadan & Alkahtani, 2017). Thus, the high frequency of school trolley carriage among secondary school children and it is considered that no previous studies provided an analysis of the heart rate and muscle activation pattern while carrying the loaded school trolley and school backpack during level, upstairs and downstairs walking.

Chapter 3: Methodology

The aim of this study was to analyze the heart rate and muscle activation pattern of trunk and lower limb while carrying a school trolley or school backpack with different loads during level, upstairs and downstairs walking in secondary school participants. It was hypothesized that with increasing load, there is as well as increase in the muscle activity and a change in the heart rate. Besides, it was hypothesized that asymmetric lifting school trolley during upstairs and downstairs walking would affect the muscle activation pattern of trunk and lower limb. Each subject was measured with a scale and measuring rod to collect his/her body weight and body height. A questionnaire was used to collect the information of the gender, age, injury history and dominant hand of the subjects. To analyze the lower limb muscle activation patterns during the carriage of different loads of school trolley and backpack. Maximum voluntary contraction (MVC) tests were performed for all examined muscles prior to the walking trial.

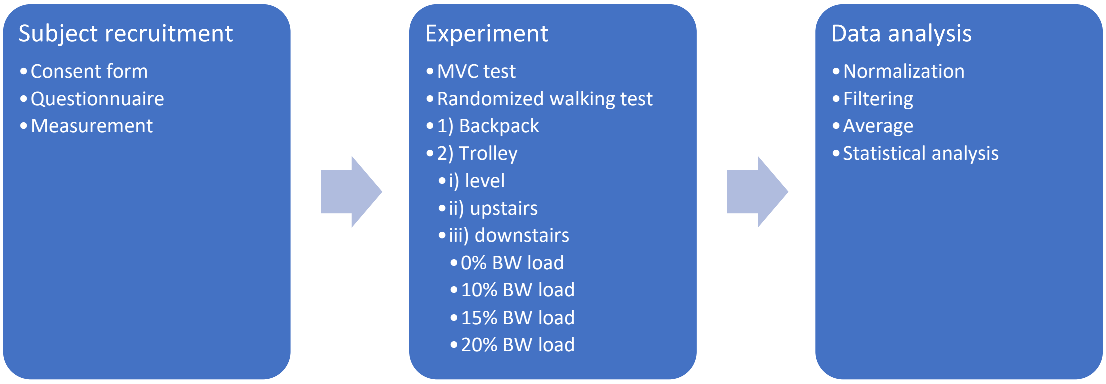

Figure 1 Study flow and different conditions of experiment

Figure 2 EMG placements

Figure 3 MVC testing posture (gastrocnemius muscle)

Figure 4 Sample of school backpack

Figure 5 Sample of school trolley

Figure 6 Sample of staircase

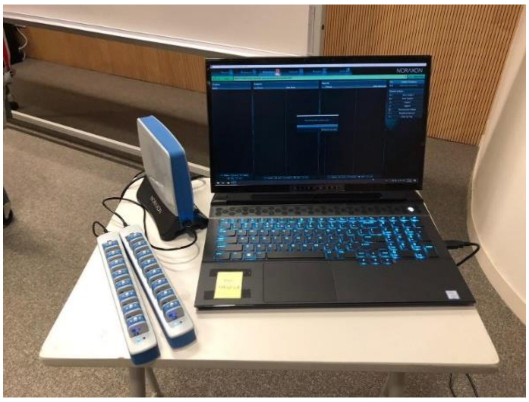

Figure 7 Sample of the surface electromyography system

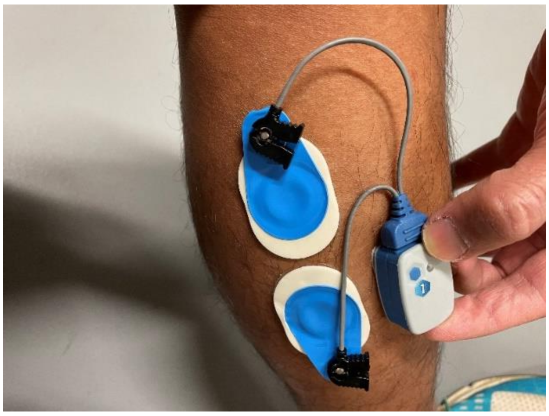

Figure 8 Sample of the sensors of electromyography

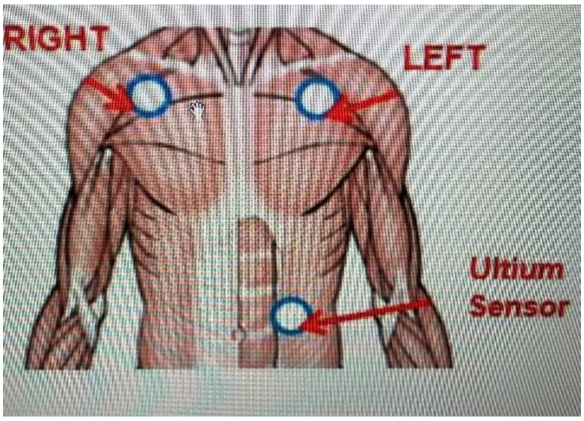

Figure 9 Sample of the locations of the heart rate sensors

Figure 10 Sample of the accelerometers

Participants

Twenty-five secondary school students (14 males and 11 females) were chosen as they represented a population that might carry school trolley and backpack for an extended time and distance without access to school storage lockers (Orantes-Gonzalez, & Heredia-Jimenez, 2019). In order to detect an effect of partial eta squared = .04 with 80% power in a one-way within-subjects ANOVA (seven groups, alpha = 0.05, non-sphericity correction = 1), G*Power suggests 25 participants were needed in the study. Subjects in the selected school who's aged were 12 to 15 years were invited, with a mean age of 13.4 (SD = 1.1) years, a mean height of 154.1 (SD = 7.7) cm, and a mean weight of 42.8 (SD = 8.0) kg to participate in the study. Subjects were excluded if they have any injury, postural deformities, spine surgery, history of low back pain and major surgery during the last 6 months.

Experimental design

Each subject was measured with a scale and measuring rod to collect his/her body weight and body height. A questionnaire was used to collect the information of the gender, age, injury history and dominant hand of the subjects. Moreover, in order to analyze the lower limb muscle activation patterns during the carriage of different loads of school trolley and backpack, maximum voluntary contraction (MVC) tests were performed for all examined muscles prior to the walking trial.

The subjects were suggested to wear appropriate clothes. But stiff or tight clothes wearing should not be used as it may produce artifacts and affect the signals of muscles. Additionally, alcohol cleaning for skin was applied on each subject to ensure good skin impedance values for measurement. It lasted for at least three minutes after the electrode's attachment, and ensured a stable electrical impedance condition for measurement. Noise level, zero offset and other possible shifts within joint movements were checked before the measurement and recording. As it is not possible to get a complete noise free recording, the amplitude spikes or random nature should not exceed 10-15 mV. Besides, the average noise level should be ranged from 1 to 3.5 mV. A signal check test was conducted to check the EMG frequency power. The subjects were asked to contract the investigated muscle about 40 – 60% of the perceived maximum contraction level against the static resistance. The characteristics of the spectrum were investigated after the data of contraction were stored (Konrad, 2007).

Maximum voluntary contraction (MVC) test

The below were the suggested MVC tests for the twelve muscles that include both the left and right sides of the gastrocnemius, tibialis anterior, semitendinosus, rectus femoris erector spinae (trunk extensor) and rectus abdominis (trunk flexor). Twelve MVC tests were carried out in different positions and the subjects had to contract the specific muscles during the test and each lasted for 3 to 4 seconds.

MVC test for rectus abdominis muscles: Subjects were in a sit up position to perform trunk flexion on a bench with the legs bent. The subjects attempted to flex the upper trunk while manual resistance was applied to the thorax and the feet of the subjects were fixed with anchor (Kumar, Narayan, & Zedka, 1996, Escamilla et al., 2006, Escamilla et al., 2010).

MVC test for erector spinae muscles: Subjects were fixed in a prone position on a bench and the torso suspended horizontally over the end of the bench. The subjects attempted to extend the upper trunk while the manual resistance was applied on the shoulders in the sagittal plane. (Burnett, Wee, Xie, Oh, Lim, & Tan, 2012, Escamilla, et al. 2010, Vera-Garcia, Moreside, & McGill, 2009).

MVC test for gastrocnemius muscles: Subjects were instructed to maintain a standing position with full extension of knees. The subjects attempted to perform ankle plantar flexion while the resistance was the subjects own body weight (Riemann, Limbaugh, Eitner & LeFavi, 2011, Schwartz, et al., 2020).

MVC test for tibialis anterior muscles: Subjects were instructed to maintain a supine position and keep the ankle, knee and knee in a neutral position to perform ankle dorsi flexion.

MVC test for rectus femoris muscles: Subjects were instructed to maintain a sitting position with hip and knee flexed 90 degrees and the subjects attempted to perform knee extension(Burnett et al., 2012).

MVC test for semitendinous muscles: Subjects were instructed to maintain a sitting position with hip and knee flexed 90 degrees and the subjects attempted to perform knee flexion (Halaki & Karen 2012).

The school trolley and backpack were filled with books and weights so that they were weighted 10%, 15% and 20% of each individual participant's body weight (BW). The net weight of unloaded school backpack (0.55 kg) was lighter than the net weight of unloaded school trolley (1.55 kg). The additional weights were used in the school backpack more than the one in school trolley. Therefore, two same magnitudes were used for comparing two modes of load carriage by using school backpack and school trolley respectively. Each subject was asked to walk (30 steps), walk upstairs (30 stairs including 4.7 m level walking, stair dimensions of 15.0 cm height and 33.0 cm depth) and walk downstairs (30 stairs including 4.7m level walking, stair dimensions of 15.0 cm height and 33.0 cm depth) at their preferred speed under different loading conditions: 1) unloaded walking as a control; 2) walking with trolley of 10% BW; 3) walking with trolley of 15% BW; 4) walking with trolley of 20% BW; 5) walking with backpack of 10% BW; 6) walking with backpack of 15% BW; 7) walking with backpack of 20% BW. The testing procedures of level walking, upstairs walking and downstairs walking were randomized. Unloaded walking was taken as the reference for studying the muscle activity change between the school trolley and backpack. The school trolley was pulled by individual's dominant hand. Each subject carried the school backpack symmetrically over two shoulders. Besides, the bottom of the school backpack level was set at the level of individual's waistline. The school backpack was a standard model (Dunlop International Limited, China, weight: 0.55 kg). Furthermore, the school trolley has two wheels and the height and weight of the school trolley is 0.46m (from the bottom of the school trolley to the handle of it) and 1.55 kg respectively. The same school trolley and backpack were used during all walking conditions for all the subjects. Subjects had a familiarization phase with the protocol which included one trial in walking 30 steps, climbing upstairs 30 stairs and climbing downstairs 30 stairs without a school backpack and trolley. One trial unloaded walking was done to ensure that the subjects familiarized themselves in different conditions. Furthermore, the subject completed each experimental condition in a random order. The subjects walked for each condition for about one minute and the subjects had at least two minutes of rest between consecutive experimental conditions to avoid fatigue. The subjects repeated the protocol twice and the average muscle activities were collected. In addition, subjects were required to wear Bio Monitor Smart Lead and heart rate measurements were included as a physiological variable (Devroey et al., 2007).

Data collection

Data collection was taken place over 16 trials. Current findings suggested that electromyography is one of the most accurate devices to investigate the disorder of musculoskeletal system (Carlo, 1997). Surface electromyography allowed the evaluation of muscular function in different individuals including heathy or injured one (Vera-Garcia, Moreside &McGill, 2009). The surface electromyography was suggested to use in biomechanical and ergonomic studies such as neuromuscular fatigue investigation. It is a safe and non-invasive tool which was applied by researchers and clinicians (Adeyemi, Rohani & Rani, 2015). Electrode sites were cleaned with alcohol to remove the dead skin, oil, and dirt. The area of electrode sites was shaved if necessary with the disposable shavers before surface electrodes to be attached to the subjects. Moreover, soft sand paper was used to abrade the skin with alcohol. It ensured the located skin impedance was reduced to 5Ω or below (Al-Khabbaz, Shimada, & Hasegawa., 2008; Li & Chow, 2017). During each trial, trunk and lower limb muscle activation patterns were recorded by Noraxon Ultium with 16-Channel wireless Surface Electromyography System (USA). (SEMG) data was collected during 5 seconds, beginning after 10 seconds initial standing mode. The walking and climbing performances were recorded by accelerometers which were built-in in the Ultium EMG senor for each foot to record the onset of each gait cycle. All trials were followed by a two minutes' rest to avoid accumulative fatigue.

Surface electromyography (SEMG)

Bilateral SEMG was utilized to study the changes in trunk and lower extremity muscle activities. SEMG activity was measured during all the walking and climbing modes.

The muscle activities included the left and right leg from four muscles which includes major hip, knee and ankle joint extensors and flexors: (Both of left and right sides of gastrocnemius, tibialis anterior, semitendinous, rectus femoris, erector spinae (trunk extensor) and rectus abdominis (trunk flexor) muscles).

Heart rate (HR)

The heart rate data was collected by the Bio Monitor Smartlead which was the built-in Ultium EMG sensor and it was utilized to study the changes in heart rate during all walking and climbing modes. The electrodes were attached on right and left of the chest muscles. The Bio Monitor was connected to the Ultium EMG sensor. The Bio Monitor detected the ECG of the subjects by three electrodes. The real time heart rate data was recorded during all the walking and climbing modes.

Data Analysis

Each subject attempted two successful trials in each loading condition. The gait cycle of each walking trial is normalized for data processing. 15 gait cycles were identified in each trial and the average of each dependent variable for each loading condition (0%, 10%, 15% and 20% BW) were used as input data. All muscles activities were normalized by Noraxon myo MUSCLETM software and the activities were shown as percentage of the maximum voluntary contraction (MVC%). The data then was filtered and averaged through Python program. Data normality was examined by the Shapiro and Wilk test in SPSS software. For each walking condition, three-way repeated measure ANOVA and two-way repeated measure ANOVA were used to analyze the effects of carrying method and weight on the mean of heart rate, both the maximum and mean of MVC% of left and right sides of muscles including tibialis anterior muscle, gastrocnemius muscle, semitendinosus muscle, rectus femoris muscle, lumbar erector spinae muscle and rectus abdominus muscle. If there was significant interaction between the two factors, one-way repeated measure ANOVA was used to determine the simple effect of each factor (SPSS version 26.0, IBM Inc., Chicago, IL, USA). Statistical significance was set at $p=0.05$. Bonferroni criterion was adopted for Post-hoc multiple comparisons. On the other hand, the paired sample t-test was used to investigate whether there was a significant difference in each dependent variable between the left and right sides of examined muscles in each walking mode of each trial. Statistical significance was set at $p = 0.05$.

Chapter 4: Data Analysis and Results

Results

Level walking (Heart rate and maximum MVC%)

Main findings of the effect of carrying methods and weight condition during level walking

The carrying of the school trolley is superior to the school backpack. Pulling school trolley with load during level walking showed significantly less muscle activation (in terms of EMG maximum MVC%) in gastrocnemius muscle, rectus femoris muscle, lumbar erector spinae muscle and rectus abdominus muscle compared with school backpack carriage.

Table 1

The effect of carrying method and weight condition (20%BW) during level walking

Variables bpm MVC%	Backpack		Trolley		p		
	Mean	SD	Mean	SD	Carrying Method	Weight	Interaction (Method*Weight)
Heart rate	130.7	20.3	133.5	18.9	0.232	0.0001**	0.392
Left tibialis anterior	69.4	39.2	125.6	69.5	0.0001**	0.372	0.119
Left gastrocnemius	75.0	24.1	67.9	22.9	0.0001**	0.07	0.599
Left semitendinosus	48.6	27.8	44.2	16.7	0.507	0.575	0.125
Left rectus femoris	66.2	28.6	56.3	23.9	0.086	0.016*	0.465
Left lumbar erector spinae	50.4	49.6	42.8	32.9	0.55	0.094	0.804
Left rectus abdominis	33.3	21.7	31.1	21.7	0.655	0.004*	0.158
Right tibialis anterior	69.3	34.5	64.4	32.6	0.01*	0.247	0.622
Right gastrocnemius	82.5	24.3	75.7	21.8	0.019*	0.211	0.426
Right semitendinosus	48.5	36.5	47.2	27.0	0.593	0.258	0.459
Right rectus femoris	68.2	24.8	54.8	25.5	0.081	0.259	0.017*
Right lumbar erector spinae	53.9	36.3	39.7	16.2	0.004**	0.034*	0.073
Right rectus abdominis	32.3	20.7	29.1	23.0	0.023*	0.8	0.304

*level of significance $p < 0.05$, ** level of significance $p < 0.01$

Table 1 showed the effects of carrying method and weight condition on heart rate (bpm) and muscle activation of trunk and lower limb (maximum MVC%) with 20%BW load during level walking.

Heart rate (bpm):

There was no significant interaction between the two factors and the effect of weight on heart rate was significant with $p < 0.001$. Heart rate was found to increase significantly with weight.

Left tibialis anterior muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of carrying method on left tibialis anterior muscle activity (maximum MVC%) was significant with $p < 0.001$. Left tibialis anterior muscle activity (maximum MVC%) was significantly higher in carrying a backpack than a trolley.

Right tibialis anterior muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of method on right tibialis anterior muscle activity (maximum MVC%) was significant with $p = 0.01$. Right tibialis anterior muscle activity (maximum MVC%) was significantly higher in carrying a backpack than a trolley.

Left gastrocnemius muscle (maximum MVC%)

There was no significant interaction between the two factors, and the effect of method on left gastrocnemius muscle activity (maximum MVC%) was significant with $p < 0.001$. Left gastrocnemius muscle activity (maximum MVC%) was significantly higher in carrying a backpack than a trolley.

Right gastrocnemius muscle (maximum MVC%)

There was no significant interaction between the two factors, and the effect of method on right gastrocnemius muscle activity (maximum MVC%) was significant with $p = 0.019$. Right gastrocnemius muscle activity (maximum MVC%) was significantly higher in carrying a backpack than a trolley.

Left semitendinosus muscle (maximum MVC%)

There was no significant interaction between the two factors, and there were no significant main effects of carrying method and weight on left semitendinosus muscle activity (maximum MVC%).

Right semitendinosus muscle (maximum MVC%)

There was no significant interaction between the two factors, and there were no significant main effects of carrying method and weight on right semitendinosus muscle activity (maximum MVC%).

Left rectus femoris muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of weight on left rectus femoris muscle activity (maximum MVC%) was significant with $p = 0.016$. Left rectus femoris muscle activity (maximum MVC%) was found to increase significantly with weight from 0% to 10% BW and decrease significantly with weight from 10% to 20% BW.

Right rectus femoris muscle (maximum MVC%)

There was a significant interaction between the two factors on right rectus femoris muscle activity with $p = 0.017$.

Left lumbar erector spinae muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left lumbar erector spinae muscle activity (maximum MVC%).

Right lumbar erector spinae (maximum MVC%)

There was no significant interaction between the two factors and the effect of method on right lumbar erector spinae muscle activity (maximum MVC%) was significant with $p=0.004$. Right lumbar erector spinae muscle activity (maximum MVC%) was significantly higher in carrying a backpack than trolley. Besides, the effect of weight on right lumbar erector spinae muscle activity (maximum MVC%) was significant with p = 0.004. Right lumbar erector spinae muscle activity (maximum MVC%) was found to decrease significantly with weight from 0% to 15% BW and increase significantly with weight from 15% to 20% BW.

Left rectus abdominis muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of weight on left rectus abdominis muscle activity (maximum MVC%) was significant with p = 0.004. Left rectus abdominis muscle activity (maximum MVC%) was found to increase significantly with weight from 0% to 20% BW.

Right rectus abdominis muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of method on right rectus abdominis muscle activity (maximum MVC%) was significant with p = 0.023. Right rectus abdominis muscle activity (maximum MVC%) was significantly higher in carrying a backpack than a trolley.

Upstairs walking (heart rate and maximum MVC%)

Main findings (maximum MVC%) of the effect of carrying methods and weight condition during upstairs walking

The carrying of the school backpack is superior to the school trolley; The backpack carriage showed significantly less muscular activities in tibialis anterior muscle, semitendinosus muscle, lumbar erector spinae muscle and rectus abdominus muscle during upstairs walking with load carriage.

Table 2:

The effect of carrying method and weight condition (20%BW) during upstairs walking

Variables bpm MVC%	Backpack		Trolley		p		
	Mean	SD	Mean	SD	Carrying Method	Weight	Interaction (Method*Weight)
Heart rate	143.9	17.8	140.7	21.1	0.988	0.0001**	0.681
Left tibialis anterior	101.6	69.0	125.6	69.5	0.519	0.109	0.05*
Left gastrocnemius	130.0	58.8	146.4	91.5	0.067	0.271	0.55
Left Semitendinosus	49.7	22.7	66.7	21.6	0.0001**	0.213	0.0001**
Left rectus femoris	167.5	61.1	177.8	75.2	0.61	0.023*	0.572
Left lumbar erector spinae	59.7	26.9	76.7	25.7	0.0001**	0.453	0.741
Left rectus abdominis	31.5	21.1	49.8	36.9	0.0001**	0.01*	0.005**
Right tibialis anterior	96.6	55.7	116.6	58.9	0.027*	0.211	0.01**
Right gastrocnemius	138.5	51.9	145.4	49.8	0.12	0.416	0.102
Right semitendinosus	62.8	38.9	80.5	40.3	0.306	0.684	0.207
Right rectus femoris	169.4	70.0	153.0	58.5	0.355	0.182	0.379
Right lumbar erector spinae	60.9	33.2	70.4	37.1	0.409	0.008**	0.006**
Right rectus abdominis	36.5	38.5	41.8	44.9	0.033*	0.516	0.068

*level of significance $p < 0.05$, ** level of significance $p < 0.01$

Table 2 showed the effects on heart rate (bpm) and muscle activation of trunk and lower limb (maximum MVC%) with 20%BW load during upstairs walking

Heart rate (bpm):

There was no significant interaction between the two factors and the effect of weight on heart rate was significant with $p<0.0001$. Heart rate was found to increase significantly with weight.

Left tibialis anterior muscle (maximum MVC%)

There was significant interaction between the two factors on left tibialis anterior muscle activity (maximum MVC%) with $p = 0.05$. Left tibialis anterior muscle activity (maximum MVC%) was found to increase significantly with $p=0.027$ in trolley carriage.

Right tibialis anterior muscle (maximum MVC%)

There was significant interaction between the two factors on right tibialis anterior muscle activity (maximum MVC%) with $p = 0.01$. The effect of method on right tibialis anterior muscle activity (maximum MVC%) was significant with $p = 0.027$. Right tibialis anterior muscle activity (maximum MVC%) was significantly higher in carrying a backpack than a trolley.

Left gastrocnemius muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left gastrocnemius muscle activity (maximum MVC%).

Right gastrocnemius muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right gastrocnemius muscle activity (maximum MVC%).

Left semitendinosus muscle (maximum MVC%)

There was significant interaction between the two factors on left semitendinosus muscle activity (maximum MVC%) with $p < 0.0001$. The effect of method on left semitendinosus muscle activity (maximum MVC%) was significant with p. < 0.0001. Left semitendinosus muscle activity (maximum MVC%) was significantly higher in carrying a backpack than a trolley. Left semitendinosus muscle activity (maximum MVC%) was found to decrease significantly in backpack carriage from 10% to 20% BW with $p < 0.0001$. Left semitendinosus muscle activity (maximum MVC%) was found to increase significantly with $p = 0.029$ in trolley carriage from 10% to 20% BW.

Right semitendinosus muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right semitendinosus muscle activity (maximum MVC%).

Left rectus femoris muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of weight on left rectus femoris muscle activity (maximum MVC%) was significant with p =

0.023. Left rectus femoris muscle (maximum MVC%) was found to increase significantly with weight from 0% to 20% BW.

Right rectus femoris muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right rectus femoris muscle activity (maximum MVC%).

Left lumbar erector spinae muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of method on left lumbar erector spinae muscle activity (maximum MVC%) was significant with $p < 0.0001$. Left lumbar erector spinae muscle activity (maximum MVC%) was significantly lower in carrying a backpack than a trolley.

Right lumbar erector spinae (maximum MVC%)

There was significant interaction between the two factors on right lumbar erector spinae muscle activity (maximum MVC%) with $p = 0.06$. The effect of weight on right lumbar erector spinae muscle activity (maximum MVC%) was significant with $p = 0.008$. Right lumbar erector spinae muscle activity (maximum MVC%) was found to increase significantly with weight from 0% to 20% BW. Right lumbar erector spinae muscle activity (maximum MVC%) was found to increase significantly with $p = 0.002$ in trolley carriage.

Left rectus abdominis muscle (maximum MVC%)

There was significant interaction between the two factors on left rectus abdominis muscle activity (maximum MVC%) with $p = 0.05$. The effect of method on left rectus abdominis muscle activity (maximum MVC%) was significant with $p = 0.01$. Left rectus abdominis muscle activity (maximum MVC%) was found significantly lower in carrying a backpack than a trolley. The effect of weight on left rectus abdominis muscle activity (maximum MVC%) was significant with $p < 0.0001$. Left rectus abdominis muscle activity (maximum MVC%) was found to increase significantly with weight from 0% to 20% BW. Left rectus abdominis muscle activity (maximum MVC%) was found to increase significantly with $p = 0.005$ in trolley carriage.

Right rectus abdominis muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of method on right rectus abdominis muscle activity (maximum MVC%) was significant with p =. 0.033. Right rectus abdominis muscle (maximum MVC%) was significantly lower in carrying a backpack than a trolley.

Downstairs walking (heart rate and maximum MVC%)

Main findings (maximum MVC%) of the effect of carrying methods and weight condition during downstairs walking

The carrying of the school backpack is superior to the school trolley as it showed significantly less muscular activities in tibialis anterior muscle, gastrocnemius muscle, lumbar erector spinae muscle, rectus abdominus muscle and rectus femoris muscle during downstairs walking with load carriage.

Table 3:

The effect of carrying method and weight condition (20% BW) during downstairs walking

Variables bpm MVC%	Backpack		Trolley		p		
	Mean	SD	Mean	SD	Carrying Method	Weight	Interaction (Method*Weight)
Heart rate	140.0	16.0	137.9	18.4	0.372	0.0001**	0.194
Left tibialis anterior	57.7	29.7	87.0	37.8	0.0001**	0.021*	0.0001**
Left gastrocnemius	71.2	29.3	96.2	59.1	0.002**	0.342	0.025*
Left semitendinosus	42.7	27.8	48.0	19.0	0.083	0.325	0.445
Left rectus femoris	141.5	61.0	135.2	71.6	0.269	0.104	0.814
Left lumbar erector spinae	61.1	64.6	63.6	28.1	0.243	0.016*	0.49
Left rectus abdominis	36.3	21.6	47.3	36.1	0.014*	0.001**	0.315
Right tibialis anterior	56.7	26.9	76.0	25.2	0.002**	0.342	0.025*
Right gastrocnemius	72.0	26.3	93.9	38.2	0.0001**	0.161	0.0001**
Right semitendinosus	41.4	31.7	62.5	60.3	0.202	0.577	0.254
Right rectus femoris	136.1	47.3	121.6	47.2	0.028**	0.719	0.327
Right lumbar erector spinae	54.1	36.4	45.5	20.4	0.046*	0.008**	0.23
Right rectus abdominis	40.5	40.1	38.4	33.7	0.695	0.654	0.569

*level of significance $p < 0.05$, ** level of significance $p < 0.01$

Table 3 showed the effects on heart rate (bpm) and muscle activation of trunk and lower limb (maximum MVC%) with 20%BW during downstairs walking.

Heart rate (bpm):

There was no significant interaction between the two factors and the effect of weight on heart rate was significant with $p < 0.0001$. Heart rate was found to increase significantly with weight.

Left tibialis anterior muscle (maximum MVC%)

There was significant interaction between the two factors on left tibialis anterior muscle activity (maximum MVC%) with $p < 0.0001$. The effect of method on left tibialis anterior muscle activity (maximum MVC%) was significant with $p < 0.0001$. Left tibialis anterior muscle activity (maximum MVC%) was found significantly lower in carrying a backpack than a trolley. The effect of weight on left tibialis anterior muscle activity (maximum MVC%) was significant with $p = 0.021$. Left tibialis anterior muscle activity was found to increase significantly with weight from 0% to 20% BW. Left tibialis anterior muscle activity (maximum MVC%) was found to decrease significantly in backpack carriage with $p = 0.048$. Left tibialis anterior muscle activity (maximum MVC%) was found to increase significantly with $p < 0.0001$ in trolley carriage.

Right tibialis anterior muscle (maximum MVC%)

There was significant interaction between the two factors on right tibialis anterior muscle activity (maximum MVC%) with $p < 0.0001$. The effect of method on right tibialis anterior muscle activity (maximum MVC%) was significant with $p < 0.0001$. Right tibialis anterior muscle activity (maximum MVC%) was found significantly lower in carrying a backpack than a trolley. The effect of weight on right tibialis anterior muscle activity (maximum MVC%) was significant with $p=0.012$. Right tibialis anterior muscle activity (maximum MVC%) was found to increase significantly with weight from 0% to 15% BW and decrease significantly with weight from 15% to 20%. Right tibialis anterior muscle activity (maximum MVC%) was found to increase significantly with $p = 0.003$ in trolley carriage from 0% to 15% BW and decrease significantly from 15% to 20% BW.

Left gastrocnemius muscle (maximum MVC%)

There was significant interaction between the two factors on left gastrocnemius muscle activity (maximum MVC%) with $p = 0.025$. The effect of method on left gastrocnemius muscle activity (maximum MVC%) was significant with $p = 0.002$. Left gastrocnemius muscle activity (maximum MVC%) was found significantly lower in carrying a backpack than a trolley. Left gastrocnemius muscle activity (maximum MVC%) was found to increase significantly with $p = 0.029$ in trolley from 0% to 10% BW and decrease significantly from 15% to 20% BW.

There was significant interaction between the two factors on right gastrocnemius muscle activity (maximum MVC%) with $p < 0.0001$. The effect of method on right gastrocnemius muscle activity (maximum MVC%) was significant with $p < 0.0001$. Right gastrocnemius muscle activity was found significantly lower in carrying a backpack than a trolley. Right gastrocnemius muscle activity (maximum MVC%) was found to increase significantly with $p < 0.0001$ in trolley carriage from 0% to 15% BW and decrease significantly from 15% to 20% BW.

Left semitendinosus muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left semitendinosus muscle activity (maximum MVC%).

Right semitendinosus muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right semitendinosus muscle activity (maximum MVC%).

Left rectus femoris muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left rectus femoris muscle activity (maximum MVC%).

Right rectus femoris muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of method on right rectus femoris muscle activity (maximum MVC%) was significant with $p = 0.028$. Right rectus femoris muscle (maximum MVC%) was found significantly higher in carrying a backpack than a trolley.

Left lumbar erector spinae muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of weight on left lumbar erector spinae muscle activity (maximum MVC%) was significant with $p = 0.016$. Left lumbar erector spinae muscle (maximum MVC%) was found to increase significantly with weight from 0% to 20% BW.

Right lumbar erector spinae muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of method on right lumbar erector spinae muscle activity (maximum MVC%) was significant with $p = 0.046$. Right lumbar erector spinae muscle (maximum MVC%) was found significantly higher in carrying a backpack than a trolley. The effect of weight on right lumbar erector spinae muscle activity (maximum MVC%) was significant with $p = 0.008$. Right lumbar erector spinae muscle (maximum MVC%) was found to decrease significantly with weight from 0% to 10% BW and increase significantly with weight from 10% to 20% BW.

Left rectus abdominis muscle (maximum MVC%)

There was no significant interaction between the two factors and the effect of method on left rectus abdominis muscle activity (maximum MVC%) was significant with p = 0.014. Left rectus abdominis muscle (maximum MVC%) was found significantly lower in carrying a backpack than a trolley. The effect of weight on left rectus abdominis muscle activity (maximum MVC%) was significant with p = 0.008. Left rectus abdominis muscle (maximum MVC%) was found to increase significantly with weight from 0% to 20% BW.

Right rectus abdominis muscle (maximum MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right rectus abdominis muscle activity (maximum MVC%).

Level walking (mean MVC%)

Left tibialis anterior muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on left tibialis anterior muscle activity (mean MVC%) was significant with $p < 0.0001$. Left tibialis anterior muscle (mean MVC%) was found significantly higher in carrying a backpack than a trolley.

Right tibialis anterior muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on right tibialis anterior muscle activity (mean MVC%) was significant with $p = 0.007$. Right tibialis anterior muscle (mean MVC%) was significantly higher in carrying a backpack than a trolley.

Left gastrocnemius muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left gastrocnemius muscle activity (mean MVC%).

Right gastrocnemius muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on right gastrocnemius muscle activity (mean MVC%) was significant with $p = 0.028$. Right gastrocnemius muscle (mean MVC%) was found significantly higher in carrying a backpack than a trolley.

Left semitendinosus muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left semitendinosus muscle activity (mean MVC%).

Right semitendinosus muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right semitendinosus muscle activity.

Left rectus femoris muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on left rectus femoris muscle activity (mean MVC%) was significant with $p = 0.026$. Left rectus femoris muscle (mean MVC%) was found significantly higher in carrying a backpack than a trolley. The effect of weight on left rectus femoris muscle activity (mean MVC%) was significant with $p = 0.011$. Left rectus femoris muscle (mean MVC%) was found to increase significantly with weight from 0% to 10% BW and decrease significantly with weight from 10% to 20%.

Right rectus femoris muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on right rectus femoris muscle activity (mean MVC%) was significant with $p = 0.006$.

Right rectus femoris muscle (mean MVC%) was found significantly higher in carrying a backpack than a trolley.

Left lumbar erector spinae muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left lumbar erector spinae muscle activity (mean MVC%).

Right lumbar erector spinae (mean MVC%)

There was significant interaction between the two factors on right lumbar erector spinae muscle activity (mean MVC%) with $p<0.0001$. The effect of method on right lumbar erector spinae muscle activity (mean MVC%) was significant with $p = 0.016$. Right lumbar erector spinae muscle activity (mean MVC%) was found significantly higher in carrying a backpack than a trolley. The effect of weight on right lumbar erector spinae muscle activity (mean MVC%) was significant with $p = 0.016$. Right lumbar erector spinae muscle activity (mean MVC%) was found to decrease significantly with weight from 0% to 10% BW and increase significantly with weight from 10% to 20% BW. Right lumbar erector spinae muscle activity (mean MVC%) was found to increase significantly with $p = 0.003$ in backpack carriage from 0% to 20% BW.

Left rectus abdominis muscle (mean MVC%)

There was significant interaction between the two factors on left rectus abdominis muscle activity (mean MVC%) with p = 0.035. The effect of weight on left rectus abdominis muscle activity (mean MVC%) was significant with p = 0.001. Left rectus abdominis muscle activity (mean MVC%) was found to increase significantly from 0% to 20% BW. Left rectus abdominis muscle activity (mean MVC%) was found to increase significantly with p<0.0001 in backpack carriage from 0% to 20% BW. Left rectus abdominis muscle activity (mean MVC%) was found to increase significantly with p = 0.031 in trolley carriage from 0% to 20% BW.

Right rectus abdominis muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on right rectus abdominis muscle activity (mean MVC%) was significant with p = 0.042. Right rectus abdominis muscle (mean MVC%) was significantly higher in carrying a backpack than a trolley.

Upstairs walking (mean MVC%)

Left tibialis anterior muscle (mean MVC%)

There was significant interaction between the two factors on left tibialis anterior muscle activity (mean MVC%) with p=0.001. The effect of method on left tibialis anterior muscle activity (mean MVC%) was significant with p = 0.002. Left tibialis anterior muscle activity (mean MVC%) was found significantly lower in carrying a backpack than a trolley The effect of weight on left tibialis anterior muscle activity (mean MVC%) was significant with p = 0.01. Left tibialis anterior muscle activity (mean MVC%) was found to increase significantly with weight from 0% to 15% BW and decrease significantly with weight from 15% to 20% BW. Right lumbar erector spinae muscle activity (mean MVC%) was found to increase significantly with p = 0.012 in trolley carriage from 0% to 15% BW and decrease significantly from 15% to 20% BW

Right tibialis anterior muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on right tibialis anterior muscle activity (mean MVC%) was significant with p = 0.007. Right tibialis anterior muscle (mean MVC%) was found significantly lower in carrying a backpack than a trolley.

Left gastrocnemius muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on left gastrocnemius muscle activity (mean MVC%) was significant with p = 0.014. Left gastrocnemius muscle (mean MVC%) was significantly lower in carrying a backpack than a trolley.

Right gastrocnemius muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right gastrocnemius muscle activity (mean MVC%).

Left semitendinosus muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on left semitendinosus muscle activity (mean MVC%) was significant with $p = 0.018$. Left gastrocnemius muscle (mean MVC%) was found significantly lower in carrying a backpack than a trolley.

Right semitendinosus muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on right semitendinosus muscle activity (mean MVC%) was significant with $p = 0.007$. Right gastrocnemius muscle (mean MVC%) was found significantly lower in carrying a backpack than a trolley.

Left rectus femoris muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of weight on left rectus femoris muscle activity (mean MVC%) was significant with $p = 0.036$. Left rectus femoris muscle (mean MVC%) was found to increase significantly with weight from 0% to 20% BW.

Right rectus femoris muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right rectus femoris muscle activity (mean MVC%).

Left lumbar erector spinae muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on left lumbar erector spinae muscle activity (mean MVC%) was significant with $p < 0.0001$. Left lumbar erector spinae muscle (mean MVC%) was found significantly lower in carrying a backpack than a trolley.

Right lumbar erector spinae (mean MVC%)

There was significant interaction between the two factors on right lumbar erector spinae muscle activity (mean MVC%) with $p < 0.0001$. The effect of weight on right lumbar erector spinae muscle activity (mean MVC%) was significant with $p < 0.0001$. Right lumbar erector spinae muscle activity (mean MVC%) was found to increase significantly from 0% to 20% BW Right lumbar erector spinae muscle activity (mean MVC%) was found to increase significantly with $p < 0.0001$ in trolley carriage from

0% to 20% BW.

Left rectus abdominis muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left rectus abdominis muscle activity (mean MVC%).

Right rectus abdominis muscle (mean MVC%)

There was significant interaction between the two factors on right rectus abdominis muscle activity (mean MVC%) with $p = 0.044$. The effect of method on right rectus abdominis muscle activity (mean MVC%) was significant with $p = 0.022$. Right rectus abdominis muscle activity (mean MVC%) was found significantly lower in carrying a backpack than a trolley.

Left tibialis anterior muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on left tibialis anterior activity (mean MVC%) was significant with $p = 0.001$. Left tibialis anterior muscle (mean MVC%) was found significantly lower in carrying a backpack than a trolley.

Right tibialis anterior muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on right tibialis anterior muscle activity (mean MVC%) was significant with $p < 0.0001$. Right tibialis anterior muscle (mean MVC%) was found significantly lower in carrying a backpack than a trolley.

Left gastrocnemius muscle (mean MVC%)

There was significant interaction between the two factors on left gastrocnemius muscle activity (mean MVC%) with $p = 0.003$. The effect of method on left gastrocnemius muscle activity (mean MVC%) was significant with $p=0.003$. Left gastrocnemius muscle activity (mean MVC%) was found significantly lower in carrying a backpack than a trolley. Left gastrocnemius muscle activity (mean MVC%) was found to increase significantly with $p = 0.047$ in trolley carriage from 0% to 10% BW and from 15% to 20% BW and decrease significantly from 10% to 15% BW.

Right gastrocnemius muscle (mean MVC%)

There was significant interaction between the two factors on right gastrocnemius muscle activity (mean MVC%) with $p < 0.0001$. The effect of method on right gastrocnemius muscle activity (mean MVC%) was significant with $p < 0.0001$. Right gastrocnemius muscle activity (mean MVC%) was found significantly lower in carrying a backpack than a trolley . Right gastrocnemius muscle activity (mean MVC%)

was found to decrease significantly with p=0.019 in backpack carriage from 0% to 15% BW and increase significantly (Figure 6.4d & f). Right gastrocnemius muscle activity (mean MVC%) was found to increase significantly with $p = 0.001$ in trolley carriage from 0% to 15% BW.

There was significant interaction between the two factors on left semitendinosus muscle activity (mean MVC%) with $p = 0.002$. The effect of method on left semitendinosus muscle activity (mean MVC%) was significant with $p < 0.0001$. Left semitendinosus muscle activity (mean MVC%) was found significantly lower in carrying a backpack than a trolley. The effect of weight on left semitendinosus muscle activity (mean MVC%) was significant with $p = 0.001$. Left semitendinosus muscle activity (mean MVC%) was found to decrease significantly with weight from 0% to 15% BW and increase significantly with weight from 15% to 20% BW.

Right semitendinosus muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right semitendinosus muscle activity (mean MVC%).

Left rectus femoris muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on left rectus femoris muscle activity (mean MVC%).

Right rectus femoris muscle (mean MVC%)

There was significant interaction between the two factors on right rectus femoris muscle activity (mean MVC%) with $p = 0.024$.

Left lumbar erector spinae muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on left lumbar erector spinae muscle activity (mean MVC%) was significant with $p = 0.033$. Left lumbar erector spinae muscle activity (mean MVC%) was found significantly lower in carrying a backpack than a trolley.

Right lumbar erector spinae muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of weight on right lumbar erector spinae muscle activity (mean MVC%) was significant with $p = 0.005$. Right lumbar erector spinae muscle activity (mean MVC%) was found to decrease significantly with weight from 0% to 10% BW and increase significantly with weight from 10% to 20% BW

Left rectus abdominis muscle (mean MVC%)

There was no significant interaction between the two factors and the effect of method on left rectus abdominis muscle activity (mean MVC%) was significant with $p = 0.004$. Left rectus abdominis muscle (mean MVC%) was found significantly lower in carrying in backpack than a trolley. The effect of weight on left rectus abdominis muscle activity (mean MVC%) was significant with $p < 0.0001$. Left rectus abdominis muscle (mean MVC%) was found to increase significantly with weight from 0% to 20% BW.

Right rectus abdominis muscle (mean MVC%)

There was no significant interaction between the two factors and no significant effect of method and weight on right rectus abdominis muscle activity (mean MVC%).

Result of asymmetrical work on the muscles

Upstairs walking

According to the paired samples t test, there was significant difference ($p = 0.031$) between the left and right side of rectus femoris muscle activities (maximum MVC%) in carrying the school trolley during upstairs walking with 20% BW load. Besides, there was a notable difference between the left and right side of lumbar erector spinae muscle activities (maximum MVC%) in carrying the school trolley during upstairs walking with 10% BW ($p = 0.01$) and 15% BW ($p = 0.042$). Moreover, there was also a significant difference between the left and right side of lumbar erector spinae muscle activities (mean MVC%) in carrying the school trolley during upstairs walking with 10% BW ($p = 0.001$) and 15% BW ($p = 0.005$).

Downstairs walking

There was significant difference between the left and right side of lumbar erector spinae muscle activities (maximum MVC%) in carrying the school trolley during downstairs walking with 10% BW ($p = 0.001$), 15% BW ($p = 0.003$) and 20% BW ($p = 0.002$). Moreover, there was significant difference between the left and right side of lumbar erector spinae muscle activities (mean MVC%) in carrying the school trolley during downstairs walking with 10% BW ($p < 0.0001$), 15% BW ($p = 0.001$) and 20% BW ($p = 0.001$).

Asymmetric work in different sides of muscles (maximum of MVC%)

Table 4

The effect of trolley on asymmetric work in different sides of muscles (maximum of MVC%)

Muscle	Left		Right		p
MVC%	Mean	SD	Mean	SD	
Lumbar erector spinae MVC% during upstairs walking by trolley with 10%BW	67.5	20.0	52.7	24.1	0.01**
Lumbar erector spinae MVC% during upstairs walking by trolley with 15%BW	73.8	21.2	62.1	24.1	0.042*
Lumbar erector spinae MVC% during downstairs walking by trolley with 10%BW	41.0	15.4	24.8	14.6	0.001**
Lumbar erector spinae MVC% during downstairs walking by trolley with 15%BW	45.5	18.2	29.0	15.2	0.003**
Lumbar erector spinae MVC% during downstairs walking by trolley with 20%BW	50.7	22.4	34.1	16.1	0.002**

*level of significance $p < 0.05$, ** level of significance $p < 0.01$

Table 4 showed the significant asymmetric work in lumbar erector spinae muscles during upstairs and downstairs walking. Males showed significantly higher muscle activation than females in carrying trolley during upstairs and downstairs walking with 10-20%BW.

Gender difference in the heart rate and muscle activation of trunk and lower limb

Table 5

Gender difference in the left side muscles (maximum of MVC%)

Muscle MVC%	Male		Female		p
	Mean	SD	Mean	SD	
Left semitendinosus MVC% during downstairs walking by trolley with 15%BW	41.2	11.9	33.0	12.5	0.008**
Left rectus femoris MVC% during level walking by trolley with 15%BW	58.8	24.5	76.3	62.2	0.009**
Left rectus femoris MVC% during level walking by trolley with 20%BW	56.4	11.9	56.0	30.5	0.024*
Left rectus femoris MVC% during upstairs walking by trolley with 20%BW	165.2	48.3	172.1	89.0	0.014*
Left lumbar erector spinae MVC% during upstairs walking by trolley with 0%BW	58.7	16.5	87.6	110.0	0.048*
Left lumbar erector spinae MVC% during upstairs walking by trolley with 10%BW	72.3	14.0	60.3	25.7	0.004**
Left lumbar erector spinae MVC% during upstairs walking by trolley with 15%BW	78.0	16.6	67.4	26.3	0.047*

*level of significance $p < 0.05$, ** level of significance $p < 0.01$

Table 5 showed the significant difference in left side muscles (maximum MVC%) between males and females.

Table 6

Gender difference in the right side muscles (maximum of MVC%)

Muscle MVC%	Male		Female		p
	Mean	SD	Mean	SD	
Right gastrocnemius MVC% during downstairs walking by trolley with 10%BW	97.3	44.4	75.3	25.7	0.031*
Right gastrocnemius MVC% during downstairs walking by trolley with 20%BW	103.7	43.3	79.3	23.9	0.035**
Right semitendinosus MVC% during level walking by backpack with 0%BW	47.2	11.3	49.2	28.3	0.004**
Right semitendinosus MVC% during level walking by backpack with 10%BW	42.4	10.2	55.6	37.1	0.003**
Right semitendinosus MVC% during level walking by trolley with 0%BW	41.8	10.5	58.2	34.2	0.003**
Right semitendinosus MVC% during downstairs walking by trolley with 15%BW	52.8	23.3	76.3	80.6	0.041*
Right semitendinosus MVC% during downstairs walking by trolley with 20%BW	49.0	24.2	82.7	89.6	0.006**
Right rectus femoris MVC% during level walking by trolley with 10%BW	61.5	21.3	77.5	48.4	0.016*
Right rectus femoris MVC% during downstairs walking by trolley with 15%BW	123.2	35.2	129.2	74.6	0.001**
Right lumbar erector spinae MVC% level downstairs walking by trolley with 0%BW	36.2	15.9	49.3	28.5	0.037*

*level of significance $p < 0.05$, ** level of significance $p < 0.01$

Table 6 showed the significant difference in right side muscles (maximum MVC%) between males and females.

Table 7

Gender difference in the left side muscles (mean of MVC%)

Muscle MVC%	Male		Female		p
	Mean	SD	Mean	SD	
Left tibialis anterior MVC% during downstairs walking by trolley with 10%BW	52.3	20.1	88.9	125.2	0.03*
Left gastrocnemius MVC% during level walking by trolley with 20%BW	30.0	12.0	57.0	88.4	0.024*
Left semitendinosus MVC% during level walking by trolley with 0%BW	24.5	9.5	29.9	32.3	0.048*
Left semitendinosus MVC% during level walking by trolley with 20%BW	22.5	10.4	62.4	120.0	0.023*
Left semitendinosus MVC% during upstairs walking by backpack with 20%BW	32.5	12.5	54.6	56.2	0.002**
Left semitendinosus MVC% during upstairs walking by trolley with 10%BW	46.2	19.7	85.2	145.1	0.037*
Left semitendinosus MVC% during upstairs walking by trolley with 15%BW	45.9	18.4	71.0	82.5	0.041*
Left rectus femoris MVC% during level walking by backpack with 20%BW	36.6	13.6	39.3	21.4	0.034*
Left rectus femoris MVC% during level walking by trolley with 15%BW	33.2	13.9	42.2	32.9	0.006**
Left rectus femoris MVC% during level walking by trolley with 20%BW	29.2	10.3	32.9	18.4	0.021*
Left rectus femoris MVC% during upstairs walking by backpack with 20%BW	93.5	33.5	93.0	58.4	0.033*
Left rectus femoris MVC% during downstairs walking by trolley with	92.3	47.6	76.0	31.7	0.034*

*level of significance $p < 0.05$, ** level of significance $p < 0.01$

Table 7 showed the significant difference in left side muscles (mean MVC%) between males and females.

Table 8

Gender difference in the right side muscles (mean of MVC%)

Muscle MVC%	Male		Female		p
	Mean	SD	Mean	SD	
Right gastrocnemius MVC% during upstairs walking by trolley with 20%BW	94.4	33.8	154.1	310.3	0.029*
Right semitendinosus MVC% during level walking by backpack with 20%BW	45.6	56.5	22.8	15.9	0.015*
Right semitendinosus MVC% during upstairs walking by backpack with 0%BW	46.1	29.1	64.6	74.7	0.047*
Right semitendinosus MVC% during downstairs walking by trolley with 20%BW	35.1	13.8	51.0	52.4	0.016*
Right rectus femoris MVC% during level walking by trolley with 10%BW	36.2	12.7	45.9	33.3	0.012*
Right rectus femoris MVC% during upstairs walking by backpack with 0%BW	78.5	30.7	96.5	54.7	0.01*
Right rectus femoris MVC% during upstairs walking by backpack with 10%BW	80.9	20.9	89.4	50.2	0.001**
Right rectus femoris MVC% during upstairs walking by backpack with 15%BW	80.8	23.6	86.3	40.5	0.009**
Right rectus femoris MVC% during upstairs walking by backpack with 20%BW	83.9	25.9	99.2	55.1	0.0001**
Right rectus femoris MVC% during upstairs walking by trolley with 0%BW	74.2	23.7	81.7	43.9	0.028*
Right rectus femoris MVC% during upstairs walking by trolley with 10%BW	81.2	17.6	78.8	41.6	0.0001**
Right rectus femoris MVC% during upstairs walking by trolley	81.0	20.9	91.7	41.9	0.022*

*level of significance $p < 0.05$, ** level of significance $p < 0.01$

Table 8 showed the significant difference in right side muscles (mean MVC%) between males and females.

Chapter 5: Discussion and Conclusions

Conclusions:

The effect of two carrying methods on the heart rate response could not be revealed in present study. The weight is the main effect on heart rate response during level walking, upstairs and downstairs walking. The heart rate response increases with the weight during level walking. Previous research found that the walking kinematics of children during level walking with 10% to 20% BW load carriage by school trolley was similar as unloaded walking condition with school backpack (Orantes-Gonzalez, Heredia-Jimenez, & Robinson, 2019). Spatiotemporal parameters such as velocity, cadence, stride length and step width were influenced by the use of school trolley during level walking with 20% BW load (Orantes-Gonzalez & Heredia-Jimenez, 2017). Previous research suggested that backpack with 10%-15% BW carriage caused significant difference in lumbopelvic coordination. These induced abnormal movements may increase the risk of spinal injury (Chow, Wang, & Pope 2014). School trolley could not be proved as an effective carrying method in upstairs and downstairs walking conditions. Significant greater EMG MVC% in the lower limbs' muscles such as tibialis anterior, gastrocnemius, rectus femoris muscle and trunk muscles such as lumbar erector spinae and rectus abdominis muscles during upstairs and downstairs walking is found. Meanwhile, the postures of some school children were altered (i.e. shifted to the unloaded side) during upstairs walking with 20% load under the observation. Present study showed less EMG (maximum and mean MVC%) in both sides of tibialis anterior muscle, both sides of gastrocnemius muscle, right lumbar erector spinae muscle, right rectus abdominis muscle in pulling trolley with load carriage during level walking. It is recommended that school trolley should not be allowed to carry not more than 20% BW load during level walking. According to the findings of the EMG MVC%, it showed that school trolley is an effective carrying method with less in lower limbs and trunk muscle activations in level walking condition. It helped the school children to relive the loading stress on the body effectively. In comparison of school backpack with school trolley during upstairs walking, this study finds that the school backpack which is superior to the school trolley in terms of less muscular activities in tibialis anterior muscle, semitendinosus muscle, lumbar erector spinae muscle and rectus abdominus muscle during upstairs walking with load carriage. In addition, this study finds that the school backpack which is superior to the school trolley in terms of less muscular activities in tibialis anterior muscle, gastrocnemius muscle, lumbar erector spinae muscle, rectus abdominus muscle, semitendinosus muscle and rectus femoris muscle during downstairs walking with load carriage, when the school backpack was compared with school trolley during downstairs walking.

In this study, the effects of carrying methods and weight on the heart rate, muscle activities (maximum and mean MVC%) of 12 muscles were investigated during three conditions which included level walking, upstairs as well as downstairs walking. The participants were required to pull a school trolley or carry a backpack during level walking as well as to carry the school trolley or backpack with load equivalent to 0%, 10%, 15% and 20% body weight (BW) during upstairs and downstairs walking. The data were analyzed using two-way repeated measures ANOVA for each walking condition with carrying method and weight as the within-subject factors (McFadyen & Winter, 1988).

Heart rate:

Previous research showed no significant difference in heart rate response with the load carriage from 0%, 8%, 10.5% to 13% BW during 15 minutes' treadmill walking (Daneshmandi, Rahmani-Nia, & Hosseini, 2008). There was no significant difference in heart rate response in 10 to 20% BW load carriage during level walking on a treadmill. However, it only showed a significant difference in heart rate from a resting status to a standing status with a load (Hong, Li, Wong, & Robinson, 2000). The results of heart rate response in the present study were different from previous studies. The mean heart rate increased significantly with the greater load carriage during the walking trials in the current study. Besides, the highest of mean heart rates during level, upstairs and downstairs walking were 129.8 (SD = 5.2), 140.1 (SD = 4.2) and 137.0 (SD = 3.6) bpm, when the carrying load was 20% BW. On the other hand, when the carrying load was 15% BW, the mean heart rates during level, upstairs and downstairs walking were 122.4 (SD = 4.3), 131.1 (SD = 4.5) and 127.3 (SD = 4.4) bpm, respectively. There was evidence that an increase in carrying load resulted in an increase in cardiovascular strain in school children. Due to the limitation of the walking environment in cause of the experiment, the subjects have to start with level walking and followed by the upstairs walking or downstairs walking. It may be one of the influence factors why the heart rate during downstairs walking is higher than level walking. These findings were comparable to those observed in adults when carrying a relatively heavy loading. Chung et al. (2005) found that the mean heart rate in level walking with 60 kg (80% BW) load carriage was significantly higher than the one in level walking with 40 kg (55% BW) load carriage. Furthermore, it was shown that it was caused by the higher intensity on workload and biomechanics demands (Chung, Lee, Lee & Choi, 2005). Additionally, carrying 25% BW load was shown to have significantly higher cardiac cost in 5 minutes' level walking on the treadmill (Ramadan & Al-Shayea, 2013). Research revealed that the heart rate was significantly higher when the subjects carried 40% BW load compared with no load carriage during 40 minutes' level walking on the treadmill (Ketko, Yanovich, Plotnik, Gefen, & Heled, 2015). Another research found that heart rate response of soldiers increased significantly when 31.4 kg load (40% BW) was carried during level walking, upstairs and downstairs walking respectively (Chatterjee et al., 2018). Moreover, other research showed the mean value of heart rate increased significantly with load during 5 minutes' level walking. There was no any tendency from 0% to 15% BW load (Devroey, Jonkers, de Becker, Lenaerts, & Spaepen, 2007). Another experimental study showed the average heart rate increased significantly with load carrying in both of the standing status and level walking condition (Holewijn, 1990).

Apart from the weight carriage, the carrying method is another factor that affects the heart rate response. There are many different ways or positions to carry the loadings. The methods of load carriage include backpack, double packs, shoulder satchel, hand bag and etc. The loads can be placed on the torso or other parts of the body. The energy expenditure and cardiovascular stress was different in different carrying methods. One review study found that higher energy cost for load carriage was needed in hand carrying method compared with the torso carrying method. Therefore, greater cardiovascular demand in hand carriage method in the soldier load carriage (Knapik, Reynolds, & Harman, 2004). There is no significant difference in heart rate between carrying a school backpack and pulling a school trolley in the present study. This implicated that the demand on cardiovascular strain between the two carrying methods was not statistically significant. Most of the school children have to walk upstairs with the school backpack or school trolley from ground floor to several floors in the school day. The subjects required to walk 30 steps in each condition such as level walking, upstairs walking and downstairs walking in the present experiment. It may not have enough accumulated walking duration and number of steps to induce the cardiovascular strain on the subjects when compared with the real situation in their daily lives. Consequently, if the school children carry the school backpack or school trolley with load for a short period of time i.e. climb one or two floors with load carriage at the school. It has no difference on the cardiovascular strain between carrying school backpack and school trolley.

Apart from the effect of load carriage, the gradient of walking is another factor which affects the heart rate. In the present study, it could not draw any conclusion to show how the gradient of walking affects the heart rate response as no significant difference is found (Chung, Lee, Lee, & Choi, 2005). The work of the downstairs walking is less than upstairs walking at a relatively smaller slope environment. The work of the downstairs walking is more if the slope of gradient is high as the body requires generating braking force to maintain balance and prevent from fall. Under a normal school or office setting environment, there is greater metabolic strain on heart rate and oxygen uptake during ascending stairs due to the gravity issue. There was a significant elevation of heart rate after the uphill walking on the treadmill when compared with the downhill walking on the treadmill without any load carriage (Agarwal, Narayan, Sharma, Singh, & Tiwari, 2017). Moreover, the heart rate response significantly increased proportionally with the increment of gradient from downhill walking (-10% to -5%) to level walking to uphill walking (5% to 10%) (Chatterjee et al., 2018). One research investigated the energy expenditure, oxygen uptake and heart rate during the ascending and descending stairs trials. The mean heart rate in the last 30 seconds during ascending stairs was higher in the one during descending stairs (Teh & Aziz, 2002). Another research showed that the cardiovascular demand was significantly less during downhill walking between -5% and -10% declined level. On the other hand, the cardiovascular demand was significantly the highest during uphill walking at 5% inclined level. However, it showed difference in the heart rate response during the downhill walking at -20% declined level. Gravity force facilitated the work in the walking at negative slope and it reflected in a significant lower heart rate response in the downhill walking between -5% to -10%. It required the body to generate braking force once the slope level reached -20% and it showed significant higher heart rate response due to the higher physiological demand (Navalta, Sedlock, & Park, 2004). A significant higher heart rate was shown in 6% inclined level when compared with the level walking on the treadmill. Besides, the heart rate increased significantly when compared with it in between faster and slower walking speed (Liu, 2007). The other research only examined the change of heart rate in different gradients and loadings' conditions. It supported significant increase in heart rate during greater gradient conditions such as 5% to 15% and heavier loading conditions such as 4.4 kg to 21.4 kg (Paul et al., 2015). Moreover, study showed that the highest heart rate response was found in the greatest gradient (20%) and the heaviest load (21.4 kg). The mean value of heart rate increased significantly with 10.7 kg to 21.4 kg load carriage during treadmill level walking and uphill walking (Chatterjeeet al., 2015). The finding in the present study showed a relative greater mean value of heart rate response in the upstairs walking compared with heart rate response during level walking and downstairs walking.

The effect of surgical mask on the response of heart rate

It is consistent with the recent study finding in relation to the implication of surgical mask use in physical education lessons. It indicated that the students with the use of surgical masks during physical education lessons showed a significant increase on cardiovascular response, face and temple temperature (Tornero-Aguilera, Rubio-Zarapuz, & Clemente-Suárez, 2021). In addition, another study supported that N95 and surgical facemasks could induce a significant influence on heart rate and thermal stress to the kids (Li et al., 2005). Nevertheless, some findings showed it differently. One study found that heart rate had no significant change during the 6-min walking test with the use of surgical mask (Cabanillas-Barea et al., 2021). Besides, there were no impairment in oxygenation or ventilation at rest or during physical activity with facemasks wearing (Shein et al., 2021). Moreover, one study found that there was no significant difference in heart rate response between the maskwalking and no-mask-walking (Akgül, Ozcan, Uzun, Gurses, & Baydil, 2021). The individuals only had minor effects on physiological variables during exercise with surgical mask or N95 respirator wearing (Epstein et al., 2020). Facemask wearing should have less effect on physiological parameters during a run (Hoffman, 2021).

During level walking condition, there is difference in muscle activation between two carrying methods.

School trolley vs School backpack:

Level walking:

Response in tibialis anterior muscle and gastrocnemius muscles activity:

Significant lower in both of the tibialis anterior muscle activity (maximum and mean MVC%) and gastrocnemius muscles activity (maximum MVC%) in carrying a backpack than in carrying a trolley during level walking. This is because it involves lack of load stress on the body during level walking as it involves in pulling the school trolley compared with carrying a school backpack. School children carry the backpack with the heavy load i.e. 20% BW behind caused the body lean forward to reduce the extra forces on the body. These extra forces alter the neutral curve and shape of the spine. It increases the muscle tension on the back and lower limbs and affects the gait so that more energy will be consumed in each step. It proved that the school trolley is beneficial to the school necessities carriage in daily living as it enhanced the efficiency of the utilization of the lower limb muscles such as tibialis anterior muscles and gastrocnemius muscles activity during level walking. The implication of this finding is that school trolley carriage required less muscle activation on both the left and right tibialis anterior muscles and gastrocnemius muscles during the level walking. The present finding also reflected the result of previous study. It showed that less adaptation in the ankle was produced as a result of the use of school trolley compared with the use of school backpack during level walking (Orantes-Gonzalez, Heredia-Jimenez, & Beneck, 2016). The muscle activity of tibialis anterior muscle increased significantly with the increment of the load carriage. It is common to find the effect of load carriage on the muscle activity of tibialis anterior muscles and gastrocnemius muscles during level walking or upstairs walking (Yali, Aiguo, Haitao, & Songqing, 2015).

Response in lumbar erector spinae muscle and rectus abdominus muscles activity:

Current study found that right lumbar erector spinae muscle and rectus abdominus muscle had significant less EMG (both of maximum and mean MVC%) in carrying school trolley than in carrying school backpack during level walking. It implied that pulling school trolley relieved the load on the loaded side (same side as the dominant hand for pulling trolley). The increase of the load carriage caused greater muscle activation on the right lumbar erector spinae muscle. The significant interaction between the carrying method and the weight which revealed school trolley required less EMG (both of maximum and mean MVC%) than school backpack during level walking. It is consistent with the previous study in which school children carried a loaded school backpack increased the forward leaning of trunk during level walking (Ramadan & Al-Shayea, 2013). More lumbar erector spinae muscle activities were induced to maintain a neutral position in carrying school backpack with heavy load i.e. 20% BW. However, there is no such situation in pulling trolley during level walking. The current finding suggested that school trolley is an effective carrying method to minimize the lumbar erector spinae muscle activation during level walking. The lumbar erector spinae muscle activity had significant interaction between the heaviness of the weight and the load carriage position. The lumbar erector spinae muscle activity on the opposite side of the load carriage showed significant higher EMG MVC% when compared with another side of the same muscle (Cook & Neumann, 1987). Another previous research discovered a significant decrease in lumbar erector spinae muscle peak EMG MVC% during level walking with load carriage (Li & Chow, 2017). The present study is different from the previous study. According to Li and Chow (2017), there were respective critical loads at 7.1 and 12.1% BW in the lumbar erector spinae and rectus abdominis muscles. It showed that the lumbar erector spinae and rectus abdominus muscles do not have any co-contraction with a specific increase in backpack load during level walking. The significant interaction between carrying method and weight on the left rectus abdominis muscle EMG (mean MVC%) implied that school trolley is less effective than school backpack to carry load from 0% to 10% BW during level walking. In contrast, if school children carry the load from 15% to 20% BW during level walking, then school trolley is more effective than school backpack. The result also showed that the school trolley is a more effective carrying method for heavier load.

Response in semitendinosus muscle and rectus femoris muscle activity:

No significant difference in both of the left and right semitendinosus muscle EMG (maximum and mean MVC%) and rectus femoris muscle EMG (maximum MVC%) during level walking. It is consistent with the findings from previous study which showed no significant change in semitendinosus muscle and rectus femoris muscle EMG MVC% with (10 to 20% BW) load carriage during standing status in carrying backpack (Al-Khabbaz, Shimada, & Hasegawa, 2008). In one systematic review and preliminary meta-analysis findings, no change in hamstring complex EMG MVC% with backpack carriage from all studies (Liew, Morris, & Netto 2016). Previous finding stated that vastus lateralis muscle EMG MVC% increased significantly with (20% to 40%) load carriage during level walking (Simpson, Munro, & Steele, 2011), but it is not exactly the same as current study. There is significant greater left rectus femoris EMG (both of maximum and mean MVC%) with the load 10% BW compared with the 0% BW load and significant decrease in the load from 10% to 20% BW. The trend of the maximum MVC% is not consistent with each other from 0% to 20% BW load during level walking. It may have carryover effect on the within-subjects design as the subjects completed 0% BW load carriage at the beginning and then followed by 10%, 15% and 20% BW load carriage. The subjects had an adaptation on the tasks and less muscle activation is needed to complete the tasks. Therefore, it showed significant less muscle activity from 10% to 20% BW load. Both of the left and right sides of rectus femoris muscles activity (maximum MVC%) showed significant higher muscle activity in carrying a school backpack than in carrying a school trolley during level walking. The implication of this finding is that school trolley carriage can minimize the muscular activation on both the left and right rectus femoris muscles during the level walking

According to the present finding, pulling school trolley with load during level walking has less muscle activation in tibialis anterior muscle, gastrocnemius muscle, rectus femoris muscle, lumbar erector spinae muscle and rectus abdominus muscle compared with carrying school backpack.

The EMG (maximum and mean of MVC%) of left and right sides of muscles including tibialis anterior muscle, gastrocnemius muscle, semitendinosus muscle, rectus femoris muscle, lumbar erector spinae muscle and rectus abdominus muscle responded differently in some conditions:

During upstairs walking condition, there are differences in muscle activation between the two carrying methods.

School trolley vs School backpack:

Upstairs walking:

Response in tibialis anterior muscle and gastrocnemius muscles activity:

It showed significant higher tibialis anterior muscle activity (maximum MVC%) when carrying school trolley than school backpack during upstairs walking. It implied that the school backpack is a more effective carrying method compared with the school trolley. The gradient of walking is another factor which affected the tibialis anterior muscles activity. It may be as a result of the school trolley been carried by the right side of the body (same side as dominant hand) during upstairs and downstairs walking. It induced an asymmetrical task to the subjects with load in carrying school trolley during the upstairs and downstairs walking. Meanwhile, it required a greater demand of tibialis anterior muscle activity for propulsion and braking. The tibialis anterior muscles act as a role to invert the feet and dorsiflex the feet during the downstairs walking. It is an implication for the previous findings from other studies, which demonstrated that the tibialis anterior muscle EMG MVC% increased significantly with the loaded backpack carriage during inclined gradient (Silder, Besier, & Delp, 2012). This is because it is impossible to pull the school trolley during the upstairs and downstairs walking. The school children must carry the school trolley by the dominant hand to walk upstairs and downstairs. This specific carrying method induced large dynamic forces during upstairs and downstairs walking (Pau, Leban, Paderi, & Nussbaum, 2013).

No significant difference in gastrocnemius muscles activity (maximum and mean MVC%) with weight in current study. It is different from the previous research which found gastrocnemius muscle EMG MVC% increased significantly with (20% to 40%) load carriage level walking (Simpson, Munro, & Steele, 2011). Previous research supported that the gastrocnemius muscle activities response was related to the upstairs and downstairs walking differently. The EMG MVC% of gastrocnemius muscle activity was significant higher during upstairs walking with slow speed (Haight, Lerner, Board, & Browning, 2014). There was a significant increase in EMG MVC% during upstairs walking with 22 kg load carrying. The medial gastrocnemius muscle activity had 16% increment in EMG MVC% when compared with unload carrying (Moffet, Richards, Malouin, & Bravo, 1993).

Response in lumbar erector spinae muscle and rectus abdominus muscles activity:

Current study found that left lumbar erector spinae muscle had significant less EMG (both of maximum and mean MVC%) in carrying school backpack than in carrying school trolley during upstairs walking. It implied that the school backpack is a more effective carrying method compared with the school trolley during upstairs walking. The increase of the load carriage caused greater muscle activation on the right lumbar erector spinae muscle. The significant interaction between the carrying method and the weight supported that school trolley required more right lumbar erector spinae muscle EMG (both of maximum and mean MVC%) than in the school backpack during upstairs walking with 15% to 20% BW load. This is because subjects could not carry the load by pulling school trolley in upstairs walking. They have to lift the school trolley by their dominant hand to climb up the stairs. The EMG MVC% in lumbar erector spinae increase with the load significantly. It revealed that higher muscle activation in the specific muscle to stabilize the spine during upstairs walking. The increase of the load carriage caused greater muscle activation on the right lumbar erector spinae muscle. Current study found that right rectus abdominis muscle has significant less EMG (both of maximum and mean MVC%) in carrying school backpack than in carrying school trolley during upstairs walking. It implied that school backpack is a more effective carrying method compared with school trolley during upstairs walking. The increase of the load carriage caused greater muscle activation on the left rectus abdominis muscle. The significant interaction between the carrying method and the weight supported that school trolley required more EMG (maximum MVC% in left side of muscle and mean MVC% in right side of muscle) than school backpack during upstairs walking. This is because subjects could not carry the load by pulling school trolley in upstairs walking. They had to lift the school trolley by their dominant hand to climb up the stairs. The EMG MVC% in rectus abdominis increased with the load significantly. It revealed that higher muscle activation in the specific muscle is to stabilize the spine during upstairs walking.

Response in semitendinosus muscle and rectus femoris muscle activity:

Left semitendinosus muscle activity (maximum MVC%) was significantly higher in carrying a trolley than a backpack during upstairs walking. It implied that the school backpack is a more effective carrying method compared with the school trolley during upstairs walking, as it showed a significant interaction between the carrying method and weight. This is consistent with the result from previous research which found the

EMG MVC% of semitendinosus muscle activity were significantly higher during upstairs walking with slow speed (Haight et al., 2014). Another research also found that there was significant increase in EMG MVC% during upstairs walking with 22 kg load-carrying. The medial hamstrings muscle activity had 16% increment in EMG MVC% when compared with the unload carrying. (Moffet, Richards, Malouin, & Bravo, 1993). However, there was no significant difference in carrying method and weight on the right side of the same muscle. The subjects carried the school trolley by the dominant hand (right side) during the upstairs walking. The center of mass of the subjects shifted to left hand side by the observation. The semitendinosus muscle is one of the primary hip extension muscles and it is responsible for climbing stairs movement. Both the right and left semitendinosus muscle activity (mean MVC%) were significantly higher in carrying the school trolley than in carrying the school backpack during upstairs walking. Present study showed significant higher left rectus femoris EMG (both of maximum and mean MVC%) with the weight during upstairs walking. And itis consistent with the previous meta-analysis findings; significant increase in quadriceps complex EMG MVC% with 20% BW load backpack carriage (Liew, Morris, & Netto, 2016).

According to the present finding, carrying school backpack with load during upstairs walking has less muscle activation in tibialis anterior muscle, semitendinosus muscle, lumbar erector spinae muscle and rectus abdominus muscle compared with carrying school trolley. No difference is found in gastrocnemius and rectus femoris muscle between carrying school trolley and school backpack. This study finds that the school backpack is superior to the school trolley in terms of less muscular activities in tibialis anterior muscle, semitendinosus muscle, lumbar erector spinae muscle and rectus abdominus muscle during upstairs walking with load carriage.

During downstairs walking condition, there are differences in muscle activation between two carrying methods.

School trolley vs School backpack:

Downstairs walking:

Response in tibialis anterior muscle and gastrocnemius muscles activity:

It showed significant higher tibialis anterior muscle activity (maximum MVC%) in carrying school trolley than school backpack during downstairs walking. It has similar response just like in upstairs walking, which implied that the school backpack is a more effective carrying method compared with the school trolley during downstairs walking.

There is a significant difference in gastrocnemius muscle EMG (maximum and mean MVC%) during downstairs walking in relation to the carrying method and the interaction between the carrying method and weight. The gastrocnemius muscle EMG MVC% increased significantly during upstairs and downstairs walking to maintain the stabilization (Spanjaard, Reeves, van Dieën, Baltzopoulos, & Maganaris,2009). Greater gastrocnemius muscles activities are found in carrying the school trolley than in carrying the school backpack during downstairs walking. It implied that the school backpack is a more effective carrying method compared with the school trolley during downstairs walking. Gastrocnemius muscle facilitated a greater ankle plantar-flexion to produce force for toe off during the upstairs walking. The significant higher EMG MVC% due to the trolley carriage by hand, required more work of the muscle to balance in the asymmetrical walking mechanics. Moreover, eccentric contraction during downstairs walking recruited more muscle activation to stabilize the body. Lengthening of the gastrocnemius muscles facilitated a greater dorsi-flexion force for heel strike during the downstairs walking. It is suggested that the school backpack is a more effective carrying method than school trolley to minimize the gastrocnemius muscle activities during downstairs walking.

Response in semitendinosus muscle and rectus femoris muscle activity:

One finding in downstairs walking showed two factors (1) carrying method, (2) weight and the interaction of carrying method and weight had significantly difference in left semitendinosus muscle activity (mean MVC%). The muscle activity increased significantly with load as the muscle prevents the hyperextension of the leg at the knee during downstairs. Greater semitendinosus muscles activities are found in carrying the school trolley than in carrying the school backpack during downstairs walking. It implied that the school backpack is a more effective carrying method compared with the school trolley during downstairs walking. The significant higher EMG MVC% due to the trolley carriage by hand, required more work of the muscle to balance in the asymmetrical walking mechanics. Moreover, eccentric contraction during downstairs walking recruited more muscle activation to stabilize the body. There is a significant interaction between carrying method and weight on the right rectus femoris muscle (mean MVC%) during downstairs walking. Greater right rectus femoris muscle activities are found in carrying the school trolley than in carrying the school backpack during downstairs walking. The significant higher EMG MVC% due to the trolley carriage by hand, required more work of the muscle to balance in the asymmetrical walking mechanics. Moreover, eccentric contraction during downstairs walking recruited more muscle activation to stabilize the body. It is therefore suggested that the school backpack is a more effective carrying method than school trolley to minimize the rectus femoris muscle activities during downstairs walking.

Response in lumbar erector spinae muscle and rectus abdominus muscles activity:

Because of the asymmetric mechanics in carrying trolley during downstairs walking, the loaded side (dominant side) showed significant less right lumbar erector spinae muscle EMG (maximum MVC%) in carrying trolley than in carrying backpack. The reason could be the muscle which is located at the unloaded side (non-dominant side) supported the majority work in stabilization of spine during the downstairs walking. It can be proved by the relative greater left lumbar erector spinae muscle EMG (mean MVC%) during downstairs walking. It is however suggested the school backpack is a more effective carrying method than school trolley to minimize the lumbar erector spinae muscle activities during downstairs walking. Results of present study suggested that school backpack carrying with load is more effective than school trolley carrying with load during downstairs walking. Less left rectus abdominis muscle EMG (maximum and mean MVC%) and right rectus abdominis muscle EMG (maximum

MVC%) was significantly found in school backpack carrying compared with school trolley carrying method. It is thus suggested that the school backpack is a more effective carrying method than the school trolley to minimize the lumbar erector spinae and rectus abdominis muscle activities during downstairs walking.

According to the present finding, carrying school backpack with load during downstairs walking has less muscle activation in tibialis anterior muscle, gastrocnemius muscle, lumbar erector spinae muscle, rectus abdominus muscle semitendinosus muscle and rectus femoris muscle compared with carrying school trolley. This study finds that the school backpack which is superior to the school trolley in terms of less muscular activities in tibialis anterior muscle, gastrocnemius muscle, lumbar erector spinae muscle, rectus abdominus muscle semitendinosus muscle and rectus femoris muscle during downstairs walking with load carriage.

Asymmetrical work between left and right sides of tibialis anterior muscle, gastrocnemius muscle, lumbar erector spinae muscle, rectus abdominus muscle semitendinosus muscle and rectus femoris muscle.

The present study showed the rectus femoris muscles in 20% BW load and lumbar erector spinae muscles in 10 to 15% BW load have significant asymmetrical muscle activation (maximum MVC%) during upstairs walking in carrying the school trolley. The lumbar spinae muscles showed asymmetrical muscle activation (maximum and mean MVC%) during downstairs walking in carrying the school trolley with 10-20% BW load. Previous research showed the asymmetrical muscle activation between the right and left sides of lumbar erector spinae muscles in carrying a shoulder bag with the load on the right side of the body (Motmans, Tomlow, &Vissers, 2006). Besides, previous study found asymmetrical work and potential excessive stress on the upper extremities in trolley with load carriage during upstairs and downstairs walking (Pau, Leban, Paderi, & Nussbaum, 2013). The present study supported the previous result in shoulder bag study as the loading on the right side of the body when the subjects carried the school trolley during upstairs and downstairs walking. There was no significant difference between left and right side of the examined muscles in carrying the school backpack during upstairs and downstairs walking. Therefore, it is suggested that the school backpack is a more effective carrying method than the school trolley to minimize the asymmetrical work in lumbar erector spinae muscle activities during upstairs and downstairs walking.

Gender difference in the response of stairs climbing activity

The current finding showed there was significant gender difference in the response of trunk and lower limb muscle activation during level walking, upstairs and downstairs walking. It is consistent with some studies, one previous study showed females showed greater lower limb kinematics such as knee medial rotation during downstairs walking (Baldon, Lobato, Furlan, & Serrão, 2013). Besides, one study found that females were more exerted than males during stairs climbing (Webb, Eves, & Kerr, 2011). Nevertheless, some current findings are not consistent with the previous study. Male showed significantly higher amplitude of EMG than females during stairs climbing (Sung & Lee Dongchul, 2009). Furthermore, males showed a significantly higher peak normalized EMG amplitude during downstairs walking (Hong, Yoon No Gregory, Lee, Kim, & Shin, 2020). The current study required loaded carriage such as 10-20% BW during upstairs and downstairs walking which is different from the previous study. Moreover, age of the subjects was not the same as in all of the studies.

Asymmetric muscles response in the use of school trolley during upstairs and downstairs walking

The present study only found there were significant asymmetric muscles responses on lumbar erector spinae muscles during upstairs and downstairs walking with 10-20% BW by the use of school trolley. It is consistent with previous finding and the asymmetric movement produced higher lumbar spinal loading and muscle force which is associated with the risk of lower back injury (Kim & Zhang, 2017). Moreover, an asymmetric lifting showed significant greater rating of perceived exertion compared with a symmetric lifting (Ramadan & Alkahtani, 2017). The one-handed lifting technique may alter the motion of the lumbar spine and research found that it produced greater risk in suffering from the lower back disorder (Allread, W. G., Marras, W. S., & Parnianpour, M., 1996). Moreover, research found that lateral shear forces and spine compression increased significantly if the lift became more asymmetric such as one hand lifting (Marras, W. S., & Davis, K. G., 1998). Thus, safe lifting strategy guidelines could be an effective measure to reduce the risk of lower back pain (Song & Qu, 2014). Research suggested that it may be not easy to control the spinal curvature which is associated with the risk of injury. It is crucial to minimize the potentially unstable and asymmetric lifting to prevent from injury (Wilson & Granata, 2003).

Limitations:

Walking speed

The walking speed varied between the subjects during the present experiment under the observation by the researcher. The subjects walked faster if the relative intensity is lower and the subjects walked slower if the relative intensity is higher. However, the walking speed was not monitored and measured during the experiment. Stepping rate may affect the heart rate response and muscle activity as the subjects had to step harder. This enhanced more recruitment on the fast twist muscle fibers and it caused higher metabolism (Teh & Aziz, 2002). The biomechanics parameters of level walking such as muscle forces and joint contact forces were affected by walking speed (Haight, Lerner, Board, & Browning, 2014). Slow walking was recommended by previous research for the patients who have low back pain as it can reduce the loads on the spine of the patients (Cheng, Chen, Chen, & Lee, 1998). Previous research found that the reduced walking speed and shortened stride length with 15% BW load carriage was found (Wang, Pascoe, & Weimar, 2001). Another research supported that the change of kinematic parameters such as joint angle and gait were influenced by the change of walking speed of the subject (Orantes-Gonzalez & Heredia-Jimenez, 2017). There was no recommended walking speed for the subjects to conduct the experiment. The subjects started the walk with their preferred speed. Thus, few of the school children in the present study walked faster than other obviously. In the present study, researcher attempted to use school trolley with 20% BW carriage, few subjects felt that it was heavy to carry the school trolley during upstairs and downstairs walking but it was not found in carrying school backpack with same load. It is different from the findings in the previous study that it was too heavy for the sedentary females to carry 20% BW backpack in walking (Smith et al., 2006).

The walking time and resting time between each trial of walking.

Pilot test was conducted before the experiment and it found some practical limitation in using EMG system to record the information of the walking trials. The walking time is limited by the EMG recording system as it is not recommended to record more than 120 seconds activity at a time. It has difficulty in doing the raw EMG data normalization and data analysis afterward. It may limit identifying the difference in heart rate response and muscle activation between the two carrying method. It may also be one of the reasons why there is no significance difference in the heart rate response between two carrying methods. Moreover, the present study reflects the short-term effect of school backpack and school trolley load carriage on the heart rate and muscle activation. It may not be applicable to long term carriage as heart rate and muscle activation pattern may vary with fatigue status.

Suggestions for further research

A metronome to maintain steady walking speed in a fixed cadence (60 steps / min) during the level walking, upstairs and downstairs walking can be considered to be utilized in the future study. The data in the present study were obtained during a short recording time i.e. 30 steps in each trial, so that longer duration changes in the tibialis anterior muscle, gastrocnemius muscle, semitendinosus muscle, rectus femoris muscle, lumbar erector spinae muscle and rectus abdominus muscle EMG MVC% were not addressed. Such a further study will need to record the EMG MVC% for longer duration. Each trial was performed for limited time duration i.e. 30 steps in each trial. Future studies should examine a greater number of steps i.e. walking from ground floor to fifth floor during upstairs and downstairs.

There was no hip belt in the school backpack that was used in the present study. Although hip belt usage may not improve the sway area (Golriz, Hebert, Foreman, & Walker, 2015), however if hip belt is present, then is suggested to be used in the future study to improve the postural stability and comfort position of backpack if longer walking time will be applied in the experiment (Mackie, Stevenson, Reid, & Legg, 2005).

Additionally, apart from the tibialis anterior muscle, gastrocnemius muscle, semitendinosus muscle, rectus femoris muscle, lumbar erector spinae muscle and rectus abdominus muscle EMG MVC%, neck muscle EMG MVC% is one of the other muscles which showed significant change when carrying 15% BW load schoolbags (Kim, Yi, Kwon, Cho, & Yoo, 2008). It is suggested to involve more muscles such as upper trapezius, sternocleidomastoid and midcervical paraspinals EMG MVC% measurement simultaneously in order to have a comprehensive analysis for the effect of load on different muscle EMG MVC%. Lastly, 10% to 20% load was used for both of the school backpack and the school trolley in the current study. Practically, school children may carry a higher load when pulling the school trolley. Future study may consider examining the effect of pulling a higher load on the muscle EMG MVC%.

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Appendix A

Questionnaire 問卷

Name 姓名:
Age 年齡:
Body height 身體高度:
Body weight 身體重量:
Dominant hand 慣用手: Right hand 右手 Left hand 左手

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
   醫生曾否說過你的心臟有問題，以及只可進行醫生建議的體能活動？
   YES 是 NO 否

2. Do you feel pain in your chest when you do physical activity?
   你進行體能活動時會否感到胸口痛？
   YES 是 NO 否

3. In the past month, have you had chest pain when you were not doing physical activity?
   過去一個月內，你曾否在沒有進行體能活動時也感到胸口痛？
   YES 是 NO 否

4. Do you lose your balance because of dizziness or do you ever lose consciousness?
   你曾否因感到暈眩而失去平衡，或曾否失去知覺？
   YES 是 NO 否

5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
   你的骨骼或關節(例如脊骨、膝蓋或髖關節)是否有毛病，且會因改變體能活動而惡化？
   YES 是 NO 否

6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
   醫生現時是否有開血壓或心臟藥物（例如 water pills）給你服用？

YES 是　　NO 否

7. Do you have Arthritis, Osteoporosis, or Back Problems?
   請問您有關節炎，骨質疏鬆症或背部問題嗎？
   YES 是　　NO 否

8. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia.
   請問您有脊髓損傷病史嗎？包括了四肢癱瘓、半身不遂等。
   YES 是　　NO 否

9. Do you have any other medical condition not listed above or do you have two or. more medical conditions?
   請問您是否有任何其他未列出的健康狀況，或者，您是否有兩種或兩種以上的健康問題？
   YES 是　　NO 否

10. Do you know of any other reason why you should not do physical activity?
    是否有其他理由令你不應進行體能活動？
    YES 是　　NO 否

Appendix B

THE EDUCATION UNIVERSITY OF HONG KONG
Department of Health and Physical Education

CONSENT TO PARTICIPATE IN RESEARCH

<The physiological variable and the muscle activation patterns of trunk and lower limb in different modes of carrying school trolley and backpack>

I ____________________hereby consent to participate in the captioned research supervised by Prof. CHOW Hung Kay Daniel and conducted byMr. PANG Siu Chuen, who are staff / student of Department of Health and Physical Education in The Education University of Hong Kong.

I understand that information obtained from this research may be used in future research and may be published. However, my right to privacy will be retained, i.e., my personal details will not be revealed.

The procedure as set out in the **attached** information sheet has been fully explained. I understand the benefits and risks involved. My participation in the project is voluntary.

I acknowledge that I have the right to question any part of the procedure and can withdraw at any time without negative consequences.

Name of participant ______________________________

Signature of participant ______________________________

Date ______________________________

INFORMATION SHEET

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You are invited to participate in a project supervised by Prof. CHOW Hung Kay Daniel and conducted by Mr. PANG Siu Chuen, who are staff / student of Department of Health and Physical Education in The Education University of Hong Kong.

The introduction of the research

The study aims to analyze the heart rate, the trunk and lower limb muscle activation patterns during different modes of carriage of school trolley and backpack. School children always carry school backpack with all the books and supplies for the whole day. The findings of the research can provide the guidelines for the carriage of school trolley and backpack.

The methodology of the research

25 school children aged between 12 and 15 years will be recruited in the study. Invitations will be sent to the secondary school to recruit subjects. Body weight and body height of the subjects will be measured. Each subject will be asked to walk along a 15 m length walkway in different modes with carriage of different loaded school trolley and backpack. The average heart rate and muscle activities will be collected. Participants will be asked to complete the experiment from December 2020 to January 2021. The experiment will take about 2 hours. Participants involve voluntarily in this study and without any compensation. The participation and data collection in this study will contribute to the purpose of research.

The potential risks of the research

Participant may feel fatigue during and after the experiment. Clear instructions of the experiment and proper supervision will be provided to the participants. Rest between each experiment trials will be arranged for the participants. Your participation in the project is voluntary. You have every right to withdraw from the study at any time without negative consequences. All information related to you will remain confidential, and will be identifiable by codes known only to the researcher. Only statistical summary results will be published in thesis submission and academic presentation.

If you would like to obtain more information about this study, please contact Mr. PANG Siu Chuen at telephone number or his supervisor Prof. CHOW Hung Kay

Daniel at telephone number . If you have any concerns about the conduct of this research study, please do not hesitate to contact the Human Research Ethics Committee by email at hrec@eduhk.hk or by mail to Research and Development Office, The Education University of Hong Kong. Thank you for your interest in participating in this study.

Mr. PANG Siu Chuen
Principal Investigator

香港教育大學

<健康及體育學系>

參與研究同意書

<在不同模式的攜帶手拉車和背包下，身體生理變化及軀幹和下肢肌肉的活化模式>

本人__________________同意參加由周鴻奇教授負責監督，彭紹銓先生執行的研究項目。他們是香港教育大學健康及體育學系的學生/教員。

本人理解此研究所獲得的資料可用於未來的研究和學術發表。然而本人有權保護自己的隱私，本人的個人資料將不能洩漏。

研究者已將所附資料的有關步驟向本人作了充分的解釋。本人理解可能會出現的風險。本人是自願參與這項研究。

本人理解我有權在研究過程中提出問題，並在任何時候決定退出研究，更不會因此而對研究工作產生的影響負有任何責任。

參加者姓名: ______________________________

參加者簽名: ______________________________

日期: ______________________________

有關資料

<在不同模式的攜帶手拉車和背包下，身體生理變化及驅幹和下肢肌肉的活化模式>

誠邀閣下參加周鴻奇教授負責監督，彭紹銓先生負責執行的研究計劃。他們是香港教育大學健康及體育學系的學生/教員。

研究計劃簡介

這項研究旨在探討在不同模式的攜帶手拉車和背包下，研究心跳及軀幹和下肢肌肉的活化模式。在學期間的兒童經常需要攜帶背包來裝書本和其他必須品上學。此研究的結果在攜帶手拉車和背包上，可向在學期間的兒童提供合適的指引。

研究方法

25 位介乎 12 至 15 歲的學童會被邀請參與研究。邀請會透過中學學校進行。研究期間會量度參與者的身高和體重。參與者需在實驗中在不同模式下攜帶不同負重的手拉車和背包。過程中平均的心跳及軀幹和下肢肌肉的活化模式會被記錄。參與者會在 2020 年 12 月至 2021 年 1 月期間完成實驗。實驗需時大約兩小時。是次研究並不為參與者提供個人利益，但所搜集數據將對研究學習動機的問題提供寶貴的資料。

說明任何風險

參與實驗期間或完成實驗後，參與者或會感到疲累。清晰的實驗指示和恰當的監察會提供予參加者。休息在每次實驗試驗期間也會安排予參與者。閣下的參與純屬自願性質。閣下享有充分的權利在任何時候決定退出這項研究，更不會因此引致任何不良後果。凡有關閣下的資料將會保密，一切資料的編碼只有研究人員得悉。資料以不記名方法和保密處理。收集的數據資料只會用於上述名稱之研究出版或學術演講。

如閣下想獲得更多有關這項研究的資料，請與彭紹銓先生聯絡，電話　　　　　或聯絡他的導師周鴻奇教授，電話

如閣下對這項研究的操守有任何意見，可隨時與香港教育大學人類實驗對象操守委員會聯絡(電郵：hrec@eduhk.hk ;地址：香港教育

大學研究與發展事務處)。

謝謝閣下有興趣參與這項研究 。

彭紹銓先生
首席研究員

Appendix C

<u>Consent Form and Information Sheet for PARENTS</u>

THE EDUCATION UNIVERSITY OF HONG KONG
Department of Health and Physical Education

CONSENT TO PARTICIPATE IN RESEARCH

<The physiological variable and the muscle activation patterns of trunk and lower limb in different modes of carrying school trolley and backpack>

I ____________________hereby consent to my child participating in the captioned research supervised by Prof. CHOW Hung Kay Daniel and conducted by Mr. PANG Siu Chuen, who are staff / students of Health and Physical Education in The Education University of Hong Kong.

I understand that information obtained from this research may be used in future research and may be published. However, our right to privacy will be retained, i.e., the personal details of my child will not be revealed.

The procedure as set out in the **<u>attached</u>** information sheet has been fully explained. I understand the benefits and risks involved. My child's participation in the project is voluntary.

I acknowledge that we have the right to question any part of the procedure and can withdraw at any time without negative consequences.

Name of participant	____________________
Signature of participant	____________________
Name of Parent or Guardian	____________________
Signature of Parent or Guardian	____________________
Date	____________________

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The potential risks of the research

Participant may feel fatigue during and after the experiment. Clear instructions of the experiment and proper supervision will be provided to the participants. Rest between each experiment trials will be arranged for the participants. Your child's participation in the project is voluntary. You and your child have / has every right to withdraw from the study at any time without negative consequences. All information related to your child will remain confidential, and will be identifiable by codes known only to the researcher. Only statistical summary results will be published in thesis submission and academic presentation.

If you would like to obtain more information about this study, please contact Mr. PANG Siu Chuen at telephone number or his supervisor Prof. CHOW Hung Kay Daniel at telephone number If you or your child have/ has any concerns about the conduct of this research study, please do not hesitate to contact the Human Research Ethics Committee by email at hrec@eduhk.hk or by mail to Research and Development Office, The Education University of Hong Kong. Thank you for your interest in participating in this study.

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Principal Investigator

香港教育大學

<健康及體育學系>

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<在不同模式的攜帶手拉車和背包下，身體生理變化及軀幹和下肢肌肉的活化模式>

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本人理解此研究所獲得的資料可用於未來的研究和學術發表。然而本人有權保護敝子弟的隱私，本人的個人資料將不能洩漏。

研究者已將所附資料的有關步驟向本人作了充分的解釋。本人理解可能會出現的風險。本人是自願讓敝子弟參與這項研究。

本人理解本人及敝子弟皆有權在研究過程中提出問題，並在任何時候決定退出研究，更不會因此而對研究工作產生的影響負有任何責任。

參加者姓名: ________________

參加者簽名: ________________

父母姓名或監護人姓名: ________________

父母或監護人簽名: ________________

日期: ________________

有關資料

<在不同模式的攜帶手拉車和背包下，身體生理變化及軀幹和下肢肌肉的活化模式>

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如閣下或貴子女對這項研究的操守有任何意見，可隨時與香港

教育大學人類實驗對象操守委員會聯絡(電郵: hrec@eduhk.hk ;地址:
香港教育大學研究與發展事務處)。

謝謝閣下有興趣參與這項研究。

彭紹銓先生
首席研究員

Appendix D

Consent Form and Information Sheet for SCHOOLS

THE EDUCATION UNIVERSITY OF HONG KONG
Department of Health and Physical Education

CONSENT TO PARTICIPATE IN RESEARCH

<The physiological variable and the muscle activation patterns of trunk and lower limb in different modes of carrying school trolley and backpack>

I ___________________hereby consent to my student participating in the captioned research supervised by Prof. CHOW Hung Kay Daniel and conducted by Mr. PANG Siu Chuen, who are staff / students of Health and Physical Education in The Education University of Hong Kong.

I understand that information obtained from this research may be used in future research and may be published. However, our right to privacy will be retained, i.e., the personal details of my student will not be revealed.

The procedure as set out in the **attached** information sheet has been fully explained. I understand the benefits and risks involved. My student's participation in the project is voluntary.

I acknowledge that we have the right to question any part of the procedure and can withdraw at any time without negative consequences.

Name of participant	______________________________
Signature of participant	______________________________
Name of School teacher	______________________________
Signature of School teacher	______________________________
Date	______________________________

INFORMATION SHEET

<The physiological variable and the muscle activation patterns of trunk and lower limb in different modes of carrying school trolley and backpack>

You are invited to participate with your students in a project supervised by Prof. CHOW Hung Kay Daniel and conducted by Mr. PANG Siu Chuen, who are staff / students of the Health and Physical Education in The Education University of Hong Kong.

The introduction of the research

The study aims to analyze the heart rate, the trunk and lower limb muscle activation patterns during different modes of carriage of school trolley and backpack. School children always carry school backpack with all the books and supplies for the whole day. The findings of the research can provide the guidelines for the carriage of school trolley and backpack.

The methodology of the research

25 school children aged between 12 and 15 years will be recruited in the study. Invitations will be sent to the secondary school to recruit subjects. Body weight and body height of the subjects will be measured. Each subject will be asked to walk along a 15 m length walkway in different modes with carriage of different loaded school trolley and backpack. The average heart rate and muscle activities will be collected. Participants will be asked to complete the experiment from December 2020 to January 2021. The experiment will take about 2 hours. Participants involve voluntarily in this study and without any compensation. The participation and data collection in this study will contribute to the purpose of research.

The potential risks of the research

Participant may feel fatigue during and after the experiment. Clear instructions of the experiment and proper supervision will be provided to the participants. Rest between each experiment trials will be arranged for the participants. Your student's participation in the project is voluntary. You and your student have / has every right to withdraw from the study at any time without negative consequences. All information related to your student will remain confidential, and will be identifiable by codes known only to the researcher. Only statistical summary results will be published in thesis submission and academic presentation.

If you would like to obtain more information about this study, please contact Mr. PANG Siu Chuen at telephone number or his supervisor Prof. CHOW Hung Kay Daniel at telephone number If you or your student have/ has any concerns about the conduct of this research study, please do not hesitate to contact the Human Research Ethics Committee by email at hrec@eduhk.hk or by mail to Research and Development Office, The Education University of Hong Kong. Thank you for your interest in participating in this study.

Mr. PANG Siu Chuen
Principal Investigator

香港教育大學

<健康及體育學系>

參與研究同意書

<在不同模式的攜帶手拉車和背包下，身體生理變化及軀幹和下肢肌肉的活化模式>

茲同意敝學生________________參加由周鴻奇教授負責監督，彭紹銓先生執行的研究項目。他們是香港教育大學健康及體育學系的學生/教員。

本人理解此研究所獲得的資料可用於未來的研究和學術發表。然而本人有權保護敝學生的隱私，本人的個人資料將不能洩漏。

研究者已將所附資料的有關步驟向本人作了充分的解釋。本人理解可能會出現的風險。本人是自願讓敝學生參與這項研究。

本人理解本人及敝學生皆有權在研究過程中提出問題，並在任何時候決定退出研究，更不會因此而對研究工作產生的影響負有任何責任。

參加者姓名: ________________

參加者簽名: ________________

校長或老師姓名: ________________

校長或老師簽名: ________________

日期: ________________

有關資料

<在不同模式的攜帶手拉車和背包下，身體生理變化及軀幹和下肢肌肉的活化模式>

誠邀閣下及貴學生參加周鴻奇教授負責監督，彭紹銓先生負責執行的研究計劃。他們是香港教育大學健康及體育學系的學生/教員。

研究計劃簡介

這項研究旨在探討在不同模式的攜帶手拉車和背包下，研究心跳及軀幹和下肢肌肉的活化模式。在學期間的兒童經常需要攜帶背包來裝書本和其他必須品上學。此研究的結果在攜帶手拉車和背包上，可向在學期間的兒童提供合適的指引。

研究方法

25 位介乎 12 至 15 歲的學童會被邀請參與研究。邀請會透過中學學校進行。研究期間會量度參與者的身高和體重。參與者需在實驗中在不同模式下攜帶不同負重的手拉車和背包。過程中平均的心跳及軀幹和下肢肌肉的活化模式會被記錄。參與者會在 2020 年 12 月至 2021 年 1 月期間完成實驗。實驗需時大約兩小時。是次研究並不為參與者提供個人利益，但所搜集數據將對研究學習動機的問題提供寶貴的資料。

說明任何風險

參與實驗期間或完成實驗後，參與者或會感到疲累。清晰的實驗指示和恰當的監察會提供予參加者。休息在每次實驗試驗期間也會安排予參與者。閣下及貴學生的參與純屬自願性質。閣下及貴學生享有充分的權利在任何時候決定退出這項研究，更不會因此引致任何不良後果。凡有關貴學生的資料將會保密，一切資料的編碼只有研究人員得悉。資料以不記名方法和保密處理。收集的數據資料只會用於上述名稱之研究出版或學術演講。

如閣下想獲得更多有關這項研究的資料，請與彭紹銓先生聯絡，電話 或聯絡他的導師周鴻奇教授，電話

如閣下或貴學生對這項研究的操守有任何意見，可隨時與香港

教育大學人類實驗對象操守委員會聯絡(電郵: hrec@eduhk.hk ;地址: 香港教育大學研究與發展事務處)。

謝謝閣下有興趣參與這項研究。

彭紹銓先生
首席研究員

Appendix E

香港教育大學
The Education University of Hong Kong

27 November 2020

Mr PANG Siu Chuen
Doctor of Education Programme
Graduate School

Dear Mr Pang,

Application for Ethical Review <Ref. no. 2020-2021-0129>

I am pleased to inform you that approval has been given by the Human Research Ethics Committee (HREC) for your research project:

Project title: The Physiological Variable and the Muscle Activation Patterns of Trunk and Lower Limb in Different Modes of Carrying School Trolley and Backpack

Ethical approval is granted for the project period from 27 November 2020 to 1 June 2021. If a project extension is applied for lasting more than 3 months, HREC should be contacted with information regarding the nature of and the reason for the extension. If any substantial changes have been made to the project, a new HREC application will be required.

Please note that you are responsible for informing the HREC in advance of any proposed substantive changes to the research proposal or procedures which may affect the validity of this ethical approval. You will receive separate notification should a fresh approval be required.

Thank you for your kind attention and we wish you well with your research.

Yours sincerely,

Patsy Chung (Ms)
Secretary
Human Research Ethics Committee

c.c. Professor CHOU Kee Lee, Chairperson, Human Research Ethics Committee

香港新界大埔露屏路十號
10 Lo Ping Road, Tai Po, New Territories, Hong Kong
T (852) 2948 8888 F (852) 2948 6000 www.eduhk.hk

Appendix F

Descriptive statistics of carrying method and weight condition (0%BW) during level walking

Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	111.2	20.0	115.2	25.2
Left tibialis anterior	76.6	54.2	66.5	44.2
Left gastrocnemius	79.2	28.0	73.4	27.8
Left semitendinosus	45.4	17.8	42.3	15.1
Left rectus femoris	61.8	36.5	59.8	30.9
Left lumbar erector spinae	38.9	15.0	36.9	15.5
Left rectus abdominis	25.7	17.9	26.3	20.6
Right tibialis anterior	70.9	39.7	69.4	39.0
Right gastrocnemius	84.9	28.8	80.7	27.3
Right semitendinosus	48.0	19.4	48.4	23.9
Right rectus femoris	61.2	32.3	69.1	35.0
Right lumbar erector spinae	41.6	17.3	41.4	22.2
Right rectus abdominis	33.9	41.3	30.5	33.7

Descriptive statistics of carrying method and weight condition (10%BW) during level walking

Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	118.4	22.5	126.7	21.4
Left tibialis anterior	71.1	42.2	68.7	42.2
Left gastrocnemius	76.0	25.5	67.5	22.3
Left semitendinosus	43.8	16.0	44.4	16.2
Left rectus femoris	71.7	31.9	68.4	33.1
Left lumbar erector spinae	35.3	17.9	36.2	15.7
Left rectus abdominis	27.3	16.2	28.7	19.0
Right tibialis anterior	73.6	43.1	68.9	35.9
Right gastrocnemius	80.4	23.5	77.8	24.7
Right semitendinosus	47.6	24.9	60.8	54.7
Right rectus femoris	71.4	26.4	67.9	34.8
Right lumbar erector spinae	41.7	20.4	38.0	17.3
Right rectus abdominis	32.6	33.1	32.0	31.0

Descriptive statistics of carrying method and weight condition (15%BW) during level walking

Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	128.9	27.0	126.1	24.1
Left tibialis anterior	73.0	43.4	65.0	39.0
Left gastrocnemius	74.3	26.7	69.9	22.2
Left semitendinosus	42.4	17.3	46.1	18.2
Left rectus femoris	68.8	29.8	65.8	43.4
Left lumbar erector spinae	35.6	16.5	37.8	17.0
Left rectus abdominis	31.7	17.3	29.7	21.8
Right tibialis anterior	71.5	41.0	67.2	40.3
Right gastrocnemius	79.7	23.7	78.0	24.7
Right semitendinosus	58.3	57.6	59.8	50.9
Right rectus femoris	70.4	23.1	61.3	30.7
Right lumbar erector spinae	41.8	19.1	37.5	16.6
Right rectus abdominis	31.1	25.6	30.5	27.5

Descriptive statistics of carrying method and weight condition (0%BW) during downstairs walking

Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	109.2	23.0	119.1	20.3
Left tibialis anterior	63.7	32.9	60.4	30.2
Left gastrocnemius	80.4	42.0	73.3	32.7
Left semitendinosus	42.0	15.0	42.6	18.9
Left rectus femoris	126.2	63.0	126.6	59.3
Left lumbar erector spinae	34.4	17.3	39.2	17.4
Left rectus abdominis	29.3	19.2	30.7	17.4
Right tibialis anterior	63.9	28.6	64.1	31.2
Right gastrocnemius	80.4	34.0	75.8	33.3
Right semitendinosus	51.8	48.8	50.4	41.9
Right rectus femoris	138.1	68.4	118.6	39.3
Right lumbar erector spinae	38.2	19.8	38.9	27.3
Right rectus abdominis	36.1	37.8	36.8	33.3

Descriptive statistics of carrying method and weight condition (10%BW) during downstairs walking

Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	121.7	14.0	126.2	22.7
Left tibialis anterior	58.0	28.4	73.6	33.7
Left gastrocnemius	69.5	24.6	88.4	52.0
Left semitendinosus	40.8	14.9	43.6	17.5
Left rectus femoris	127.0	60.6	120.3	46.3
Left lumbar erector spinae	29.9	16.0	55.3	20.7
Left rectus abdominis	31.7	18.8	38.9	18.4
Right tibialis anterior	61.9	31.6	73.4	32.2
Right gastrocnemius	74.7	25.2	88.5	39.0
Right semitendinosus	47.8	42.3	49.0	27.8
Right rectus femoris	124.6	40.0	123.4	47.0
Right lumbar erector spinae	38.0	17.9	32.2	18.3
Right rectus abdominis	38.5	35.7	39.6	37.3

Descriptive statistics of carrying method and weight condition (15%BW) during downstairs walking

Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	126.8	21.6	124.7	16.3
Left tibialis anterior	56.5	30.2	77.9	30.1
Left gastrocnemius	67.9	25.6	87.6	34.9
Left semitendinosus	37.9	12.6	44.7	18.4
Left rectus femoris	133.1	65.2	125.2	57.3
Left lumbar erector spinae	49.6	94.8	55.3	20.7
Left rectus abdominis	34.9	22.3	44.8	36.8
Right tibialis anterior	61.1	32.4	94.8	54.6
Right gastrocnemius	70.4	25.3	97.4	40.5
Right semitendinosus	53.2	57.5	62.2	53.7
Right rectus femoris	131.0	44.0	125.6	53.1
Right lumbar erector spinae	39.7	21.2	37.8	18.9
Right rectus abdominis	35.7	29.2	38.0	31.4

Descriptive statistics of carrying method and weight condition (0%BW) during upstairs walking

Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	118.6	26.0	124.0	26.3
Left tibialis anterior	99.4	79.1	92.1	73.3
Left gastrocnemius	126.8	56.1	127.4	56.1
Left semitendinosus	57.7	23.7	54.0	28.1
Left rectus femoris	148.8	66.8	147.9	60.6
Left lumbar erector spinae	53.4	15.8	70.3	69.8
Left rectus abdominis	31.2	25.4	33.0	27.1
Right tibialis anterior	97.9	54.4	89.5	47.6
Right gastrocnemius	146.6	62.3	142.8	61.2
Right semitendinosus	71.0	40.6	76.0	52.2
Right rectus femoris	154.5	73.2	146.8	64.4
Right lumbar erector spinae	55.3	19.8	51.1	19.2
Right rectus abdominis	40.2	56.0	40.8	57.2

Descriptive statistics of carrying method and weight condition (10%BW) during upstairs walking

Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	132.5	24.5	131.6	18.8
Left tibialis anterior	105.9	75.6	99.7	41.7
Left gastrocnemius	131.3	51.5	148.3	82.7
Left semitendinosus	58.5	27.6	64.7	33.5
Left rectus femoris	160.0	76.5	168.0	65.9
Left lumbar erector spinae	52.4	18.1	67.5	20.0
Left rectus abdominis	33.4	23.5	39.5	28.1
Right tibialis anterior	97.1	50.3	106.4	53.9
Right gastrocnemius	146.5	55.0	149.4	58.9
Right semitendinosus	74.8	59.1	78.8	46.4
Right rectus femoris	153.0	65.0	151.4	62.5
Right lumbar erector spinae	56.8	20.6	52.7	24.1
Right rectus abdominis	42.8	56.2	44.5	56.2

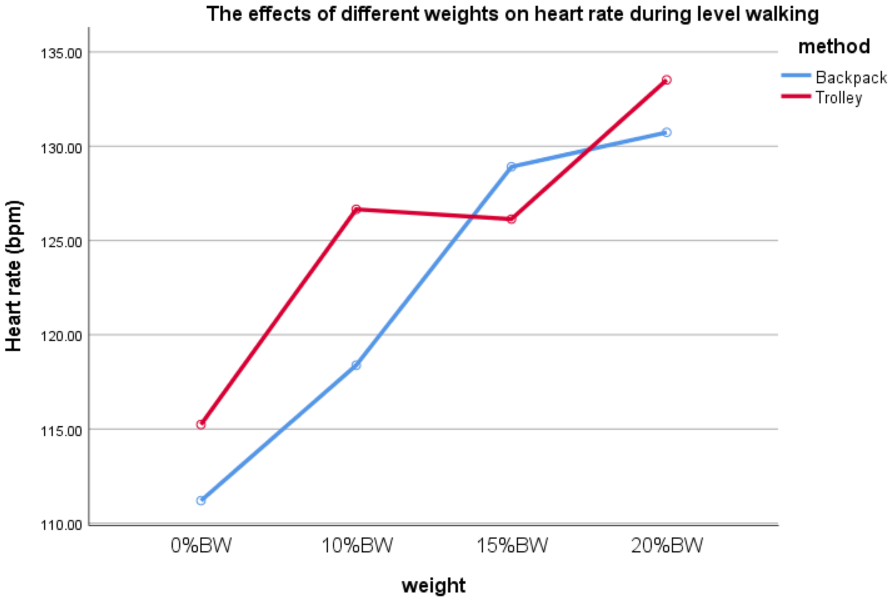
Descriptive statistics of carrying method and weight condition (15%BW) during upstairs walking

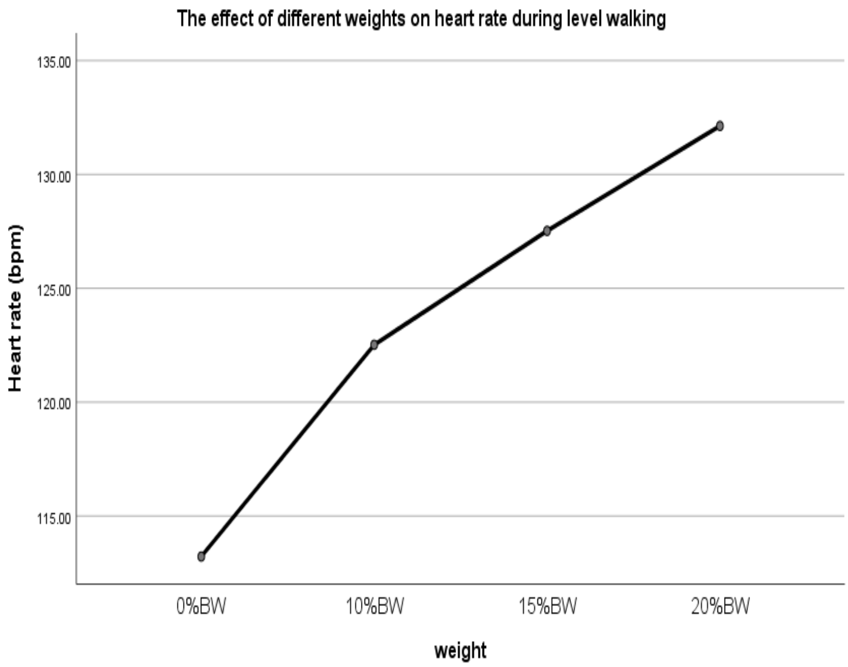
Variables Heart rate: bpm Muscle activation: MVC%	Backpack		Trolley	
	Mean	SD	Mean	SD
Heart rate	135.3	22.9	134.2	16.0
Left tibialis anterior	98.7	70.0	107.1	41.4
Left gastrocnemius	136.6	69.9	142.1	79.3
Left semitendinosus	50.3	26.8	68.9	33.3
Left rectus femoris	167.6	67.1	163.6	60.4
Left lumbar erector spinae	51.2	18.3	73.8	21.2
Left rectus abdominis	33.2	20.9	47.4	43.2
Right tibialis anterior	91.4	50.0	107.4	45.7
Right gastrocnemius	143.1	54.4	160.1	62.5
Right semitendinosus	76.3	65.4	74.0	39.9
Right rectus femoris	162.4	64.3	162.7	64.9
Right lumbar erector spinae	57.4	23.3	62.1	24.1
Right rectus abdominis	34.8	38.8	38.6	46.1

Result of **heart rate** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	474.126	1.506	.232	.059	1.506	.218
weight	**3**	**3279.884**	**16.300**	**.000**	**.404**	**48.900**	**1.000**
method * weight	3	259.292	1.013	.392	.040	3.038	.264

a. Computed using alpha = .05

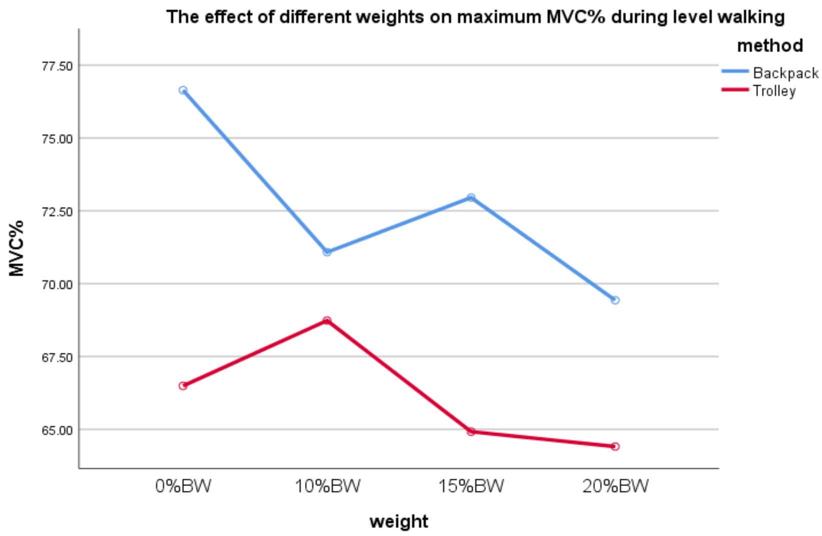


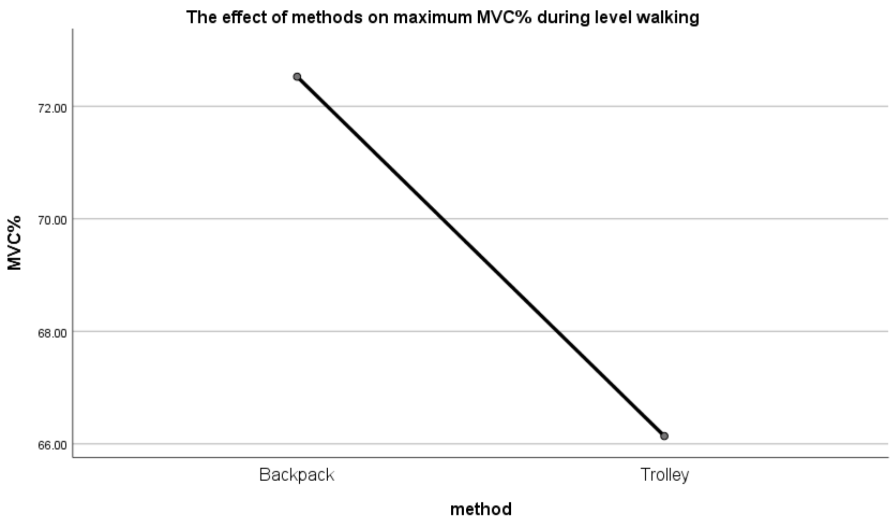


Result of **left tibialis anterior muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**2040.131**	**25.120**	**.000**	**.511**	**25.120**	**.998**
weight	1.394	405.242	.934	.372	.037	1.302	.173
method * weight	3	146.057	2.021	.119	.078	6.063	.499

a. Computed using alpha = .05

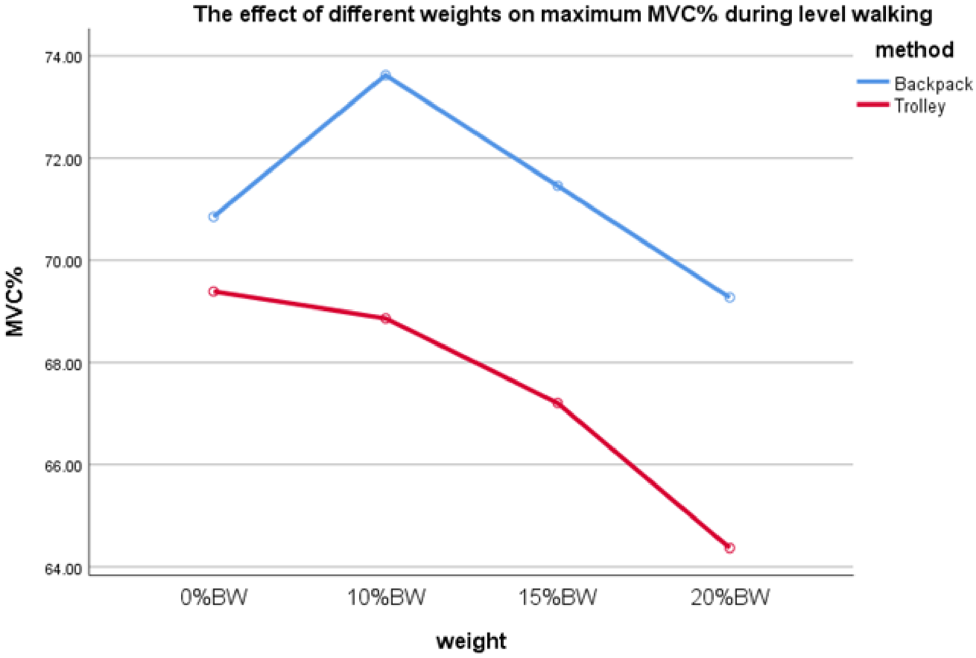


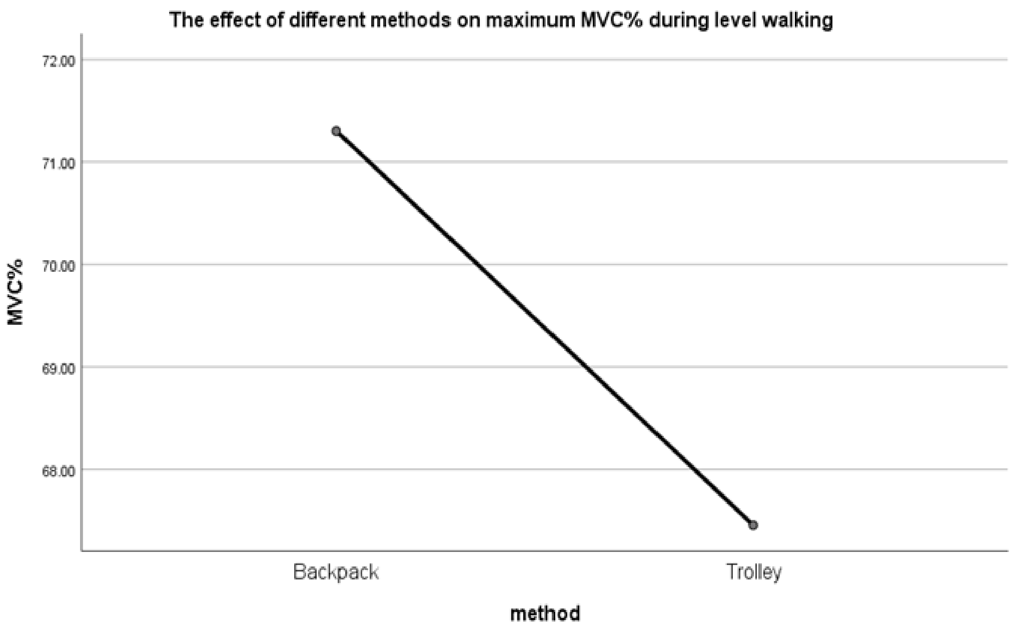


Result of **right tibialis anterior muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**740.161**	**7.768**	**.010**	**.245**	**7.768**	**.762**
weight	3	176.623	1.410	.247	.055	4.229	.359
method * weight	2.287	42.626	.519	.622	.021	1.187	.137

a. Computed using alpha = .05

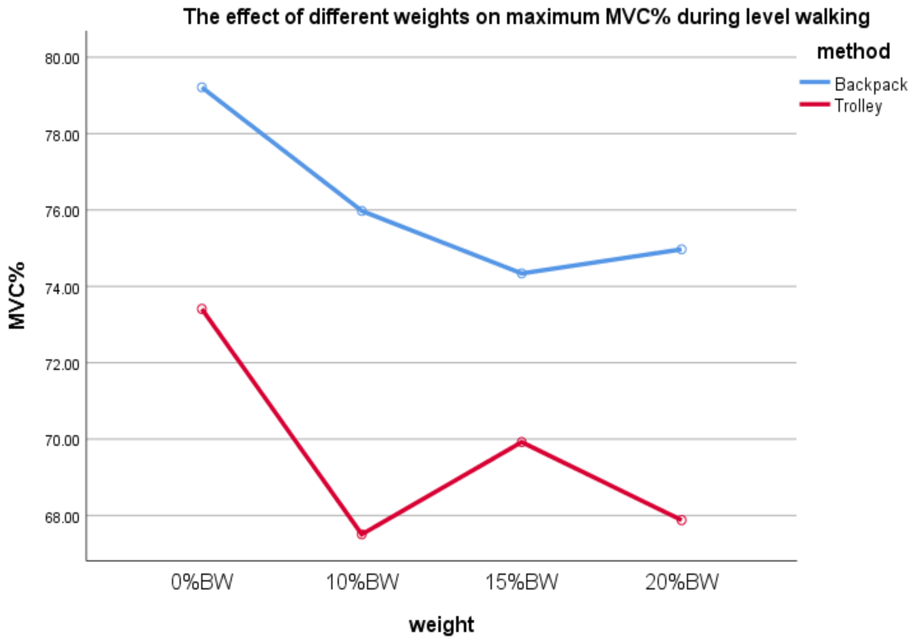


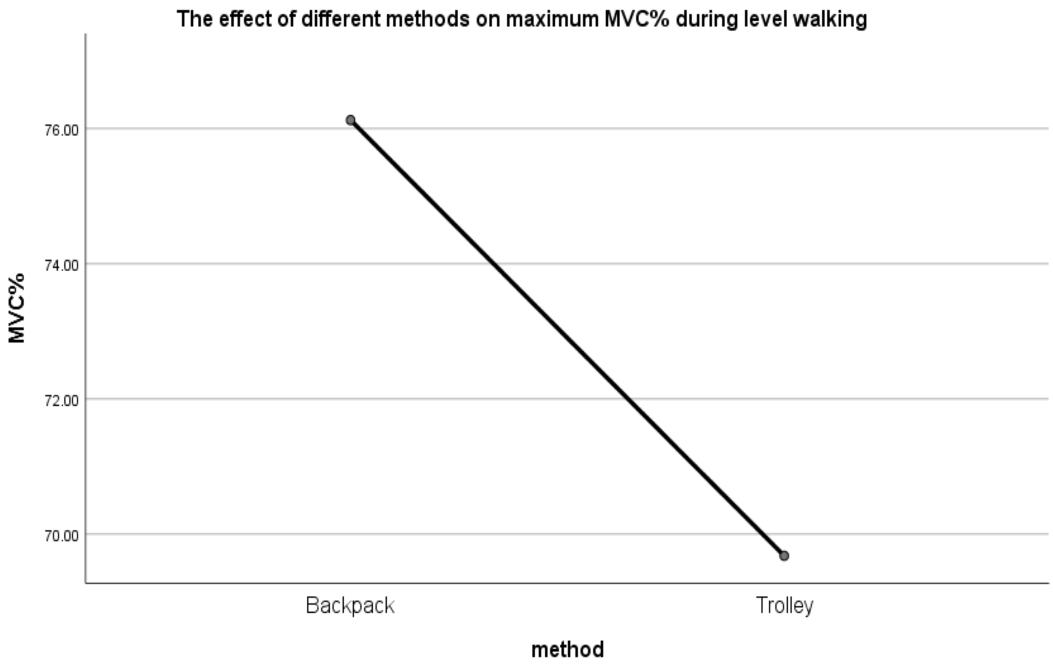


Result of **left gastrocnemius muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**2077.649**	**30.123**	**.000**	**.557**	**30.123**	**1.000**
weight	1.701	462.949	2.971	.070	.110	5.052	.505
method * weight	3	37.712	.628	.599	.025	1.883	.175

a. Computed using alpha = .05

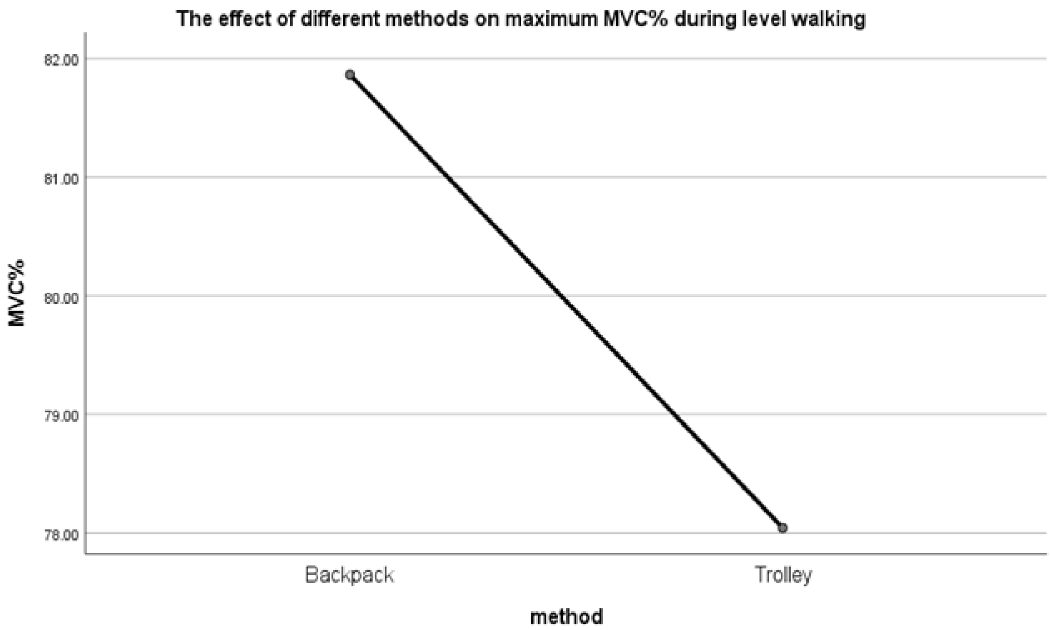




Result of **right gastrocnemius muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**729.648**	**6.287**	**.019**	**.208**	**6.287**	**.672**
weight	1.655	325.130	1.632	.211	.064	2.700	.297
method * weight	1.949	97.509	.863	.426	.035	1.681	.188

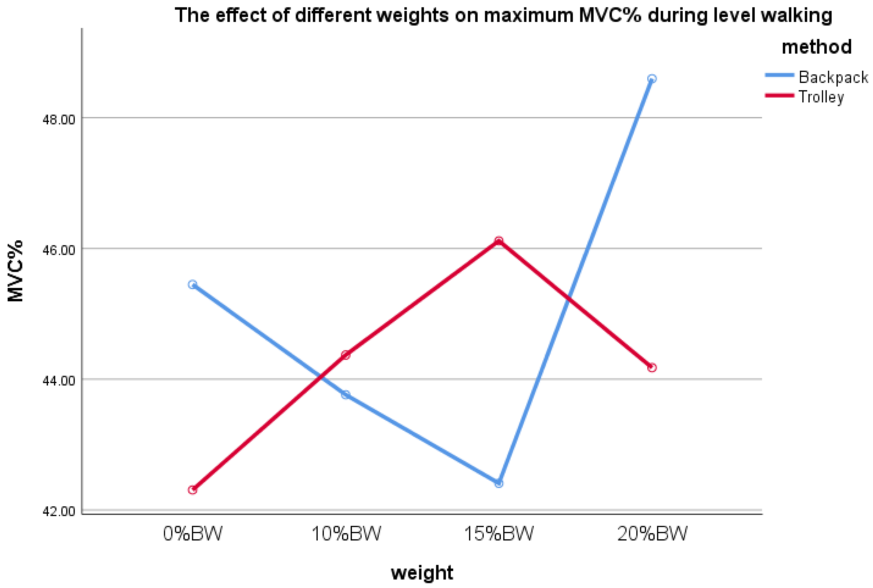
a. Computed using alpha = .05



Result of **left semitendinosus muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	32.932	.453	.507	.019	.453	.099
weight	1.825	112.438	.533	.575	.022	.973	.129
method * weight	1.436	355.843	2.347	.125	.089	3.370	.377

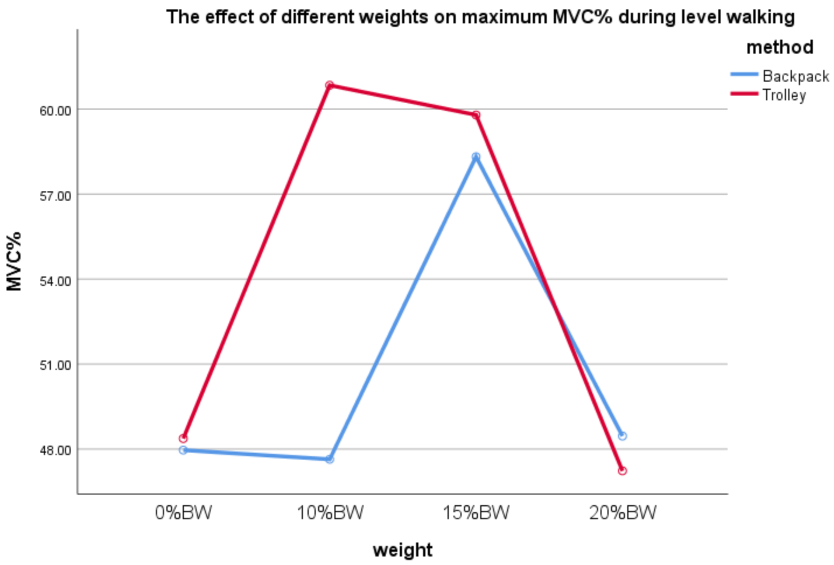
a. Computed using alpha = .05



Result of **right semitendinosus muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	600.265	.294	.593	.012	.294	.082
weight	1.935	2230.029	1.395	.258	.055	2.699	.280
method * weight	3	542.250	.873	.459	.035	2.620	.232

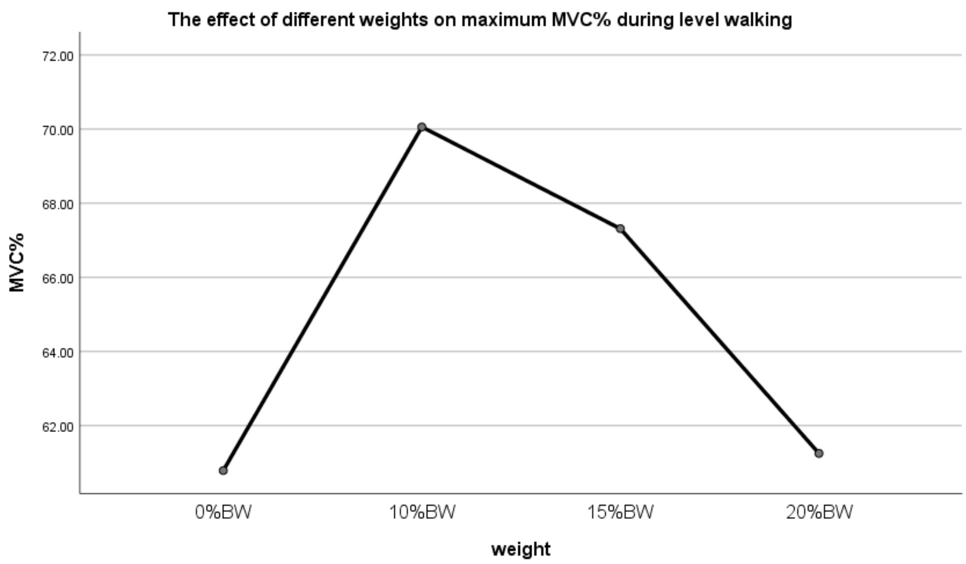
a. Computed using alpha = .05



Result of **left rectus femoris muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	1042.010	3.204	.086	.118	3.204	.405
weight	**3**	**1044.078**	**3.657**	**.016**	**.132**	**10.970**	**.779**
method * weight	1.704	289.252	.735	.465	.030	1.252	.157

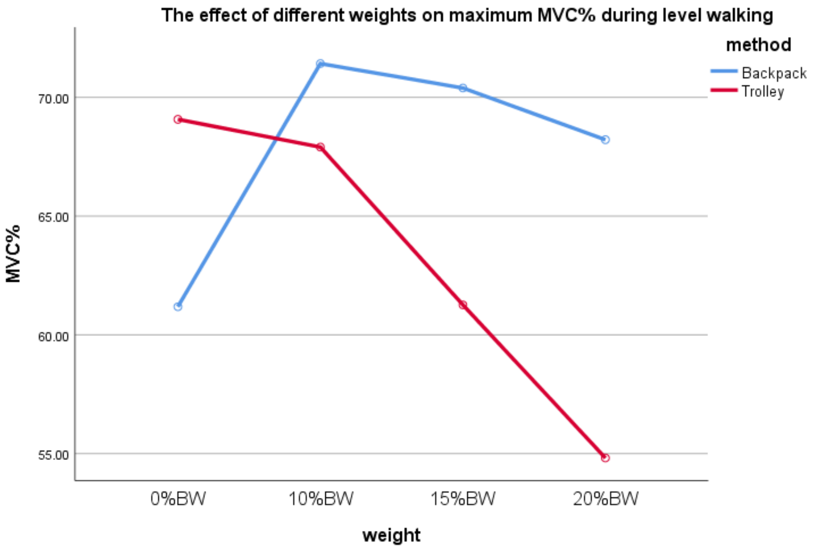
a. Computed using alpha = .05



Result of **right rectus femoris muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	1030.740	3.308	.081	.121	3.308	.415
weight	1.722	971.777	1.392	.259	.055	2.397	.264
method * weight	**2.230**	**1430.177**	**4.195**	**.017**	**.149**	**9.354**	**.746**

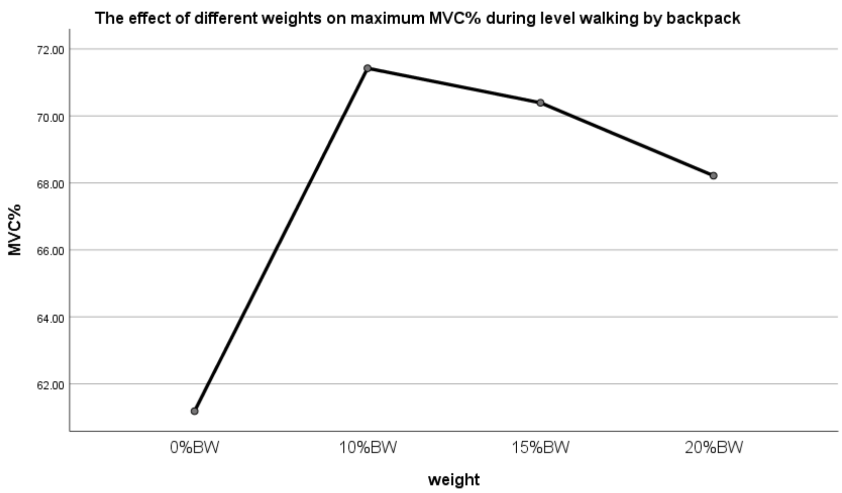
a. Computed using alpha = .05



Result of **right rectus femoris muscle** during **level walking** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	2.055	776.97	2.272	.112	.086	4.670	.447

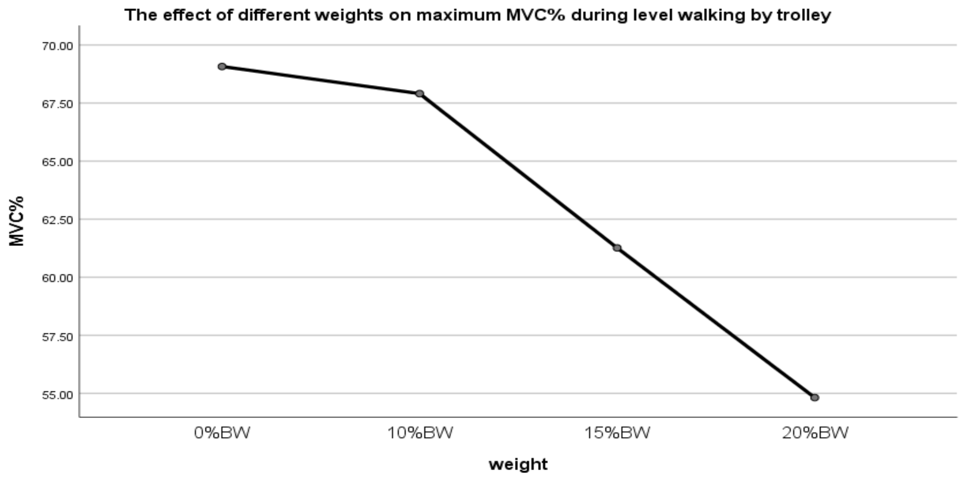
a. Computed using alpha = .05



Result of **right rectus femoris muscle** during **level walking** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	2.162	1511.186	2.593	.080	.098	5.606	.514

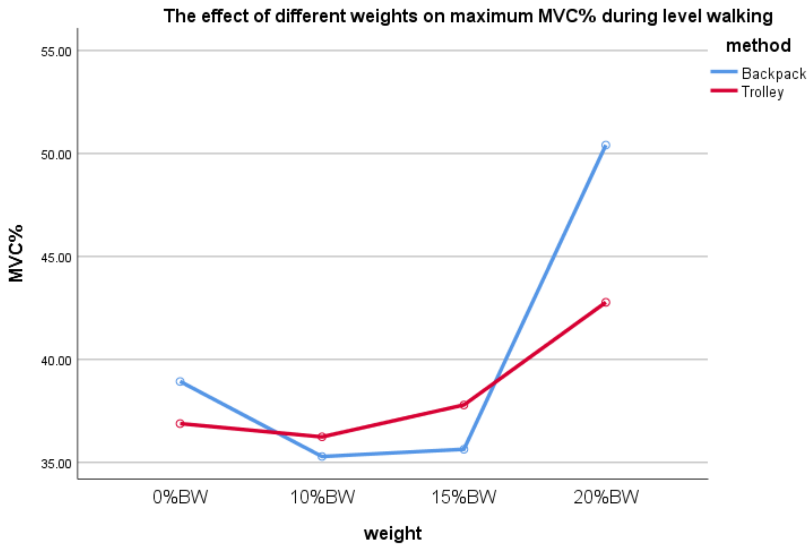
a. Computed using alpha = .05



Result of **left lumbar erector spinae muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	135.122	.349	.550	.014	.349	.088
weight	1.244	2986.986	2.852	.094	.106	3.547.	.412
method * weight	1.096	652.527	.804	.389	.032	.882	.143

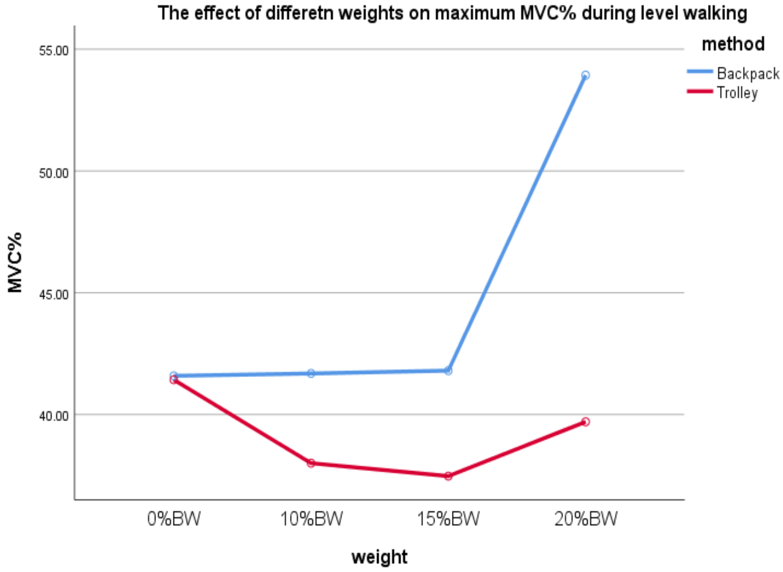
a. Computed using alpha = .05

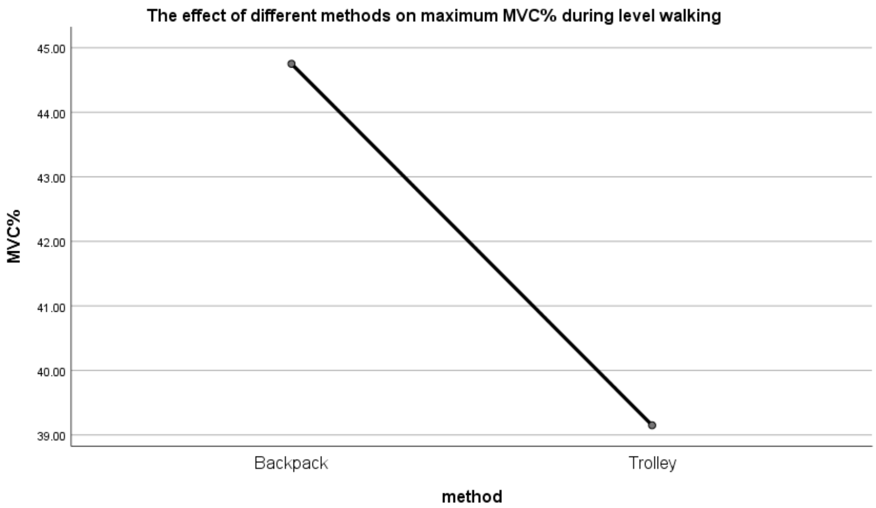


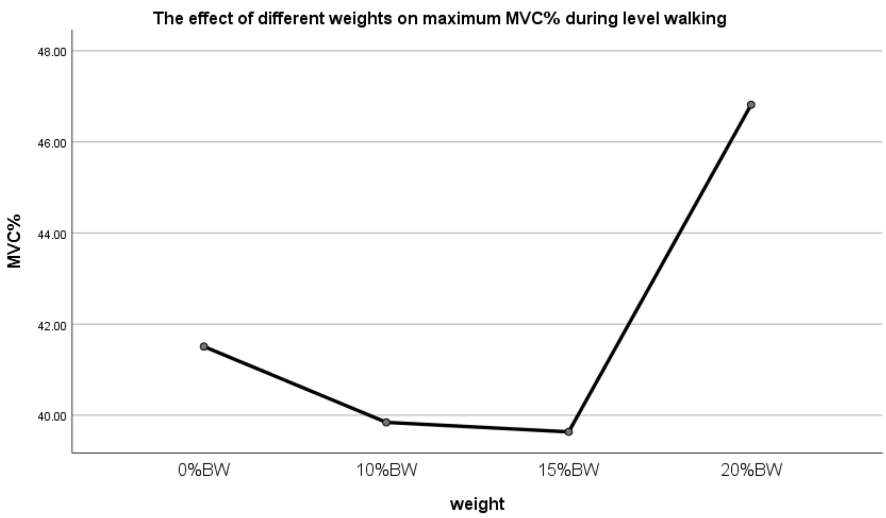
Result of **right lumbar erector spinae muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**1568.985**	**10.200**	**.004**	**.298**	**10.200**	**.865**
weight	**1.725**	**976.222**	**3.900**	**.034**	**.140**	**6.727**	**.629**
method * weight	1.706	801.264	2.920	.073	.108	4.983	.499

a. Computed using alpha = .05


The effect of differetn weights on maximum MVC% during level walking
method
Backpack
Trolley
55.00
50.00
45.00
40.00
MVC%
0%BW
10%BW
15%BW
20%BW
weight

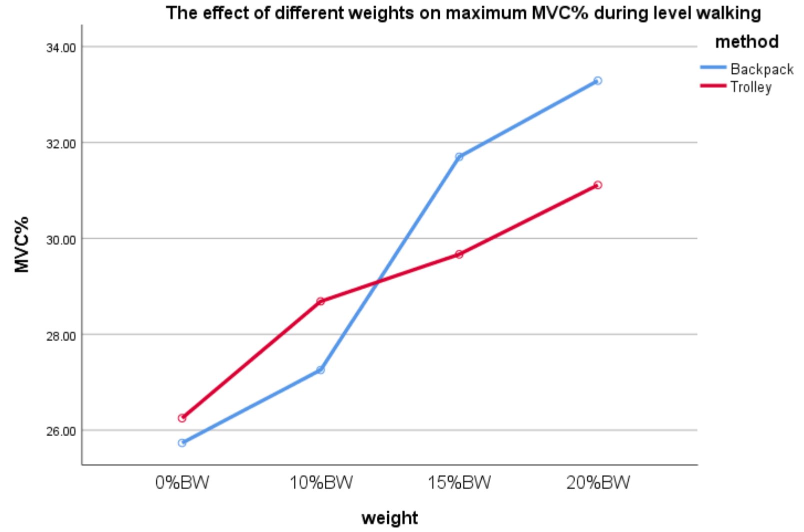

The effect of different methods on maximum MVC% during level walking
45.00
44.00
43.00
42.00
41.00
40.00
39.00
MVC%
Backpack
Trolley
method

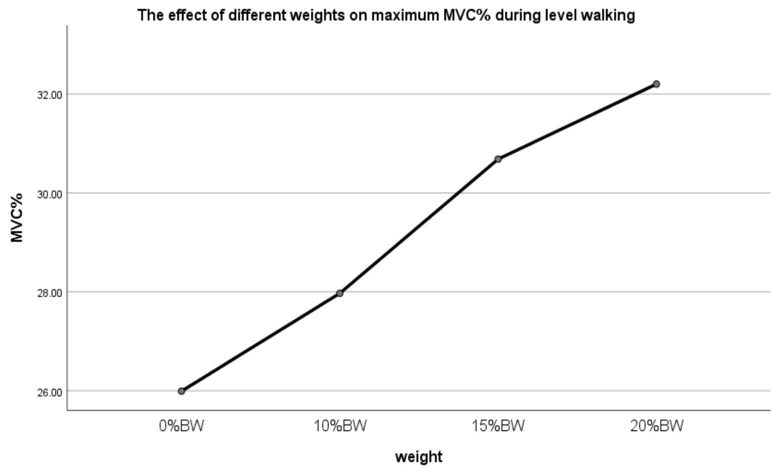

The effect of different weights on maximum MVC% during level walking
48.00
46.00
44.00
42.00
40.00
MVC%
0%BW
10%BW
15%BW
20%BW
weight

Result of **left abdominal muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	16.000	.205	.655	.008	.205	.072
weight	**2.088**	**551.203**	**6.199**	**.004**	**.205**	**12.940**	**.884**
method * weight	3	41.297	1.785	.158	.069	5.354	.446

a. Computed using alpha = .05

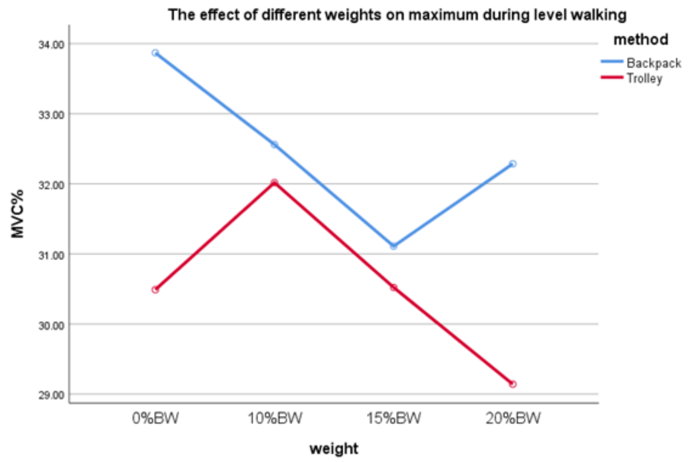


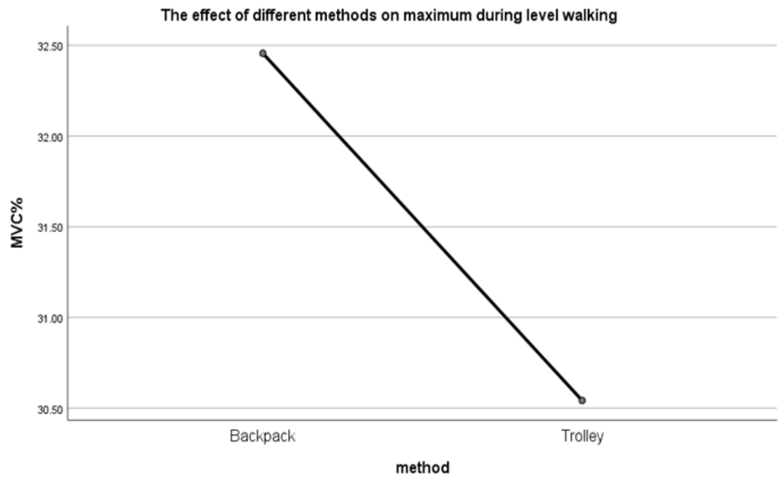


Result of **right abdominal muscle** during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**183.195**	**5.853**	**.023**	**.196**	**5.853**	**.641**
weight	1.088	99.735	.080	.800	.003	.087	.059
method * weight	1.915	47.655	1.219	.304	.048	2.335	.248

a. Computed using alpha = .05

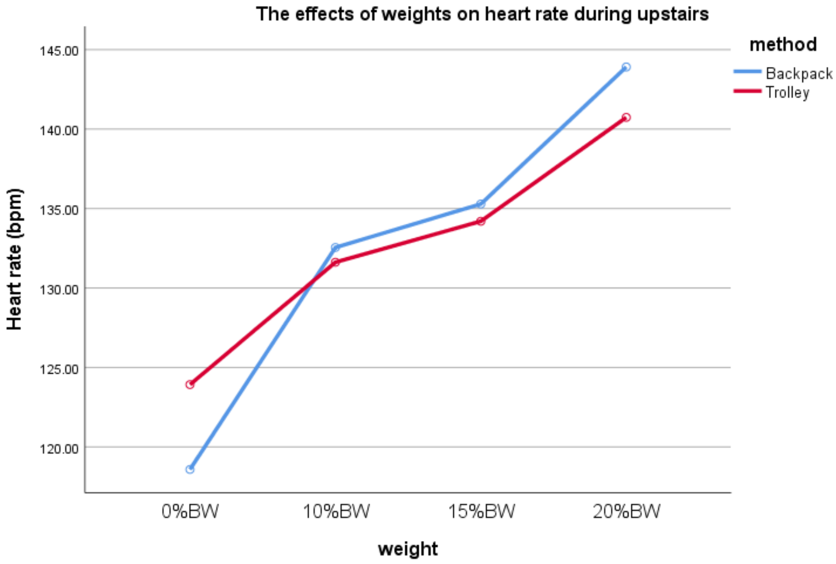


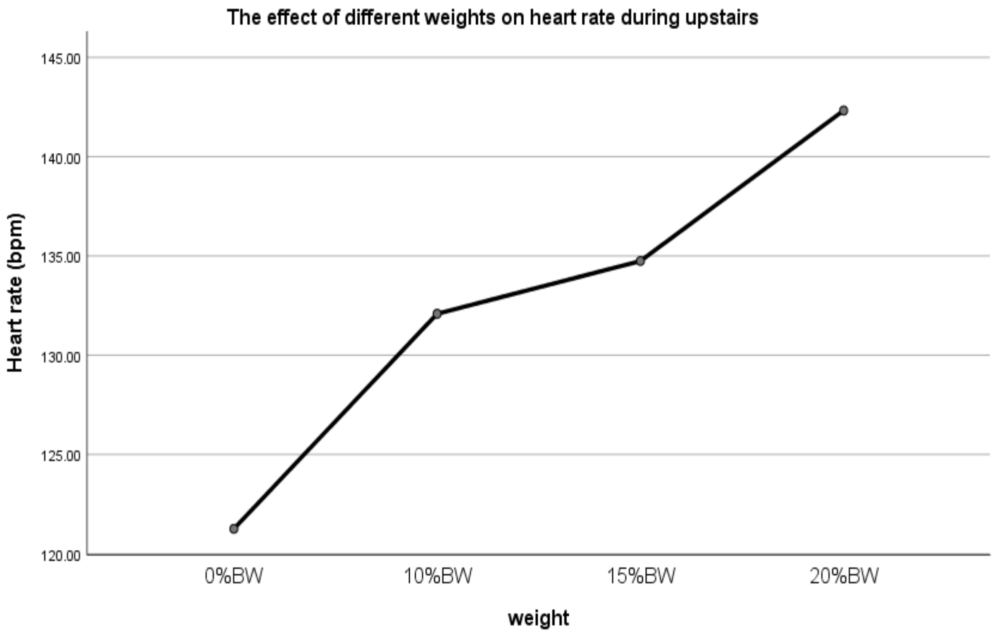


Result of **heart rate** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	.075	.000	.988	.000	.000	.050
weight	**2.608**	**4374.733**	**11.439**	**.000**	**.323**	**34.316**	**.999**
method * weight	2.781	182.654	.504	.681	.021	1.513	.148

a. Computed using alpha = .05

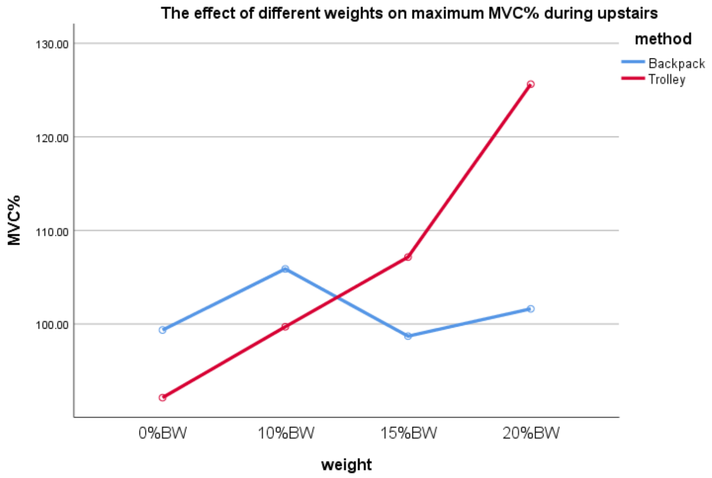




Result of **left tibialis anterior muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	1134.168	.428	.519	.018	.428	.096
weight	1.449	5633.184	2.525	.109	.095	3.659	.404
method * weight	1.335	6062.765	3.781	**.050**	**.136**	**5.049**	**.539**

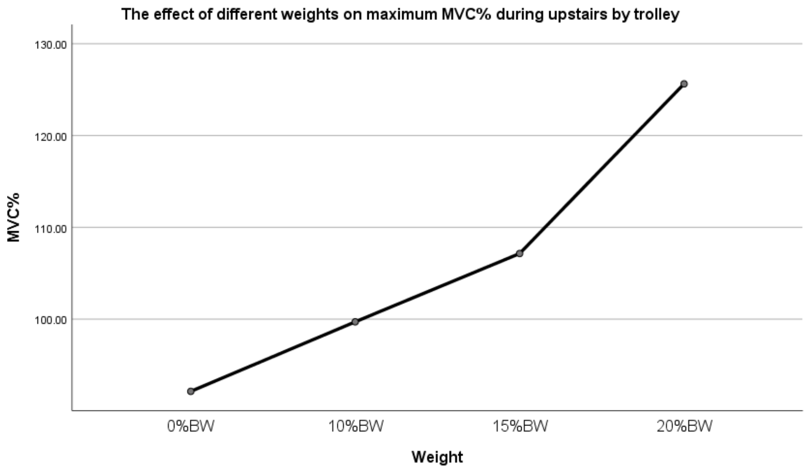
a. Computed using alpha = .05



Result of **left tibialis anterior muscle** during **upstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**3**	**5155.455**	**3.249**	**.027**	**.119**	**9.746**	**.723**

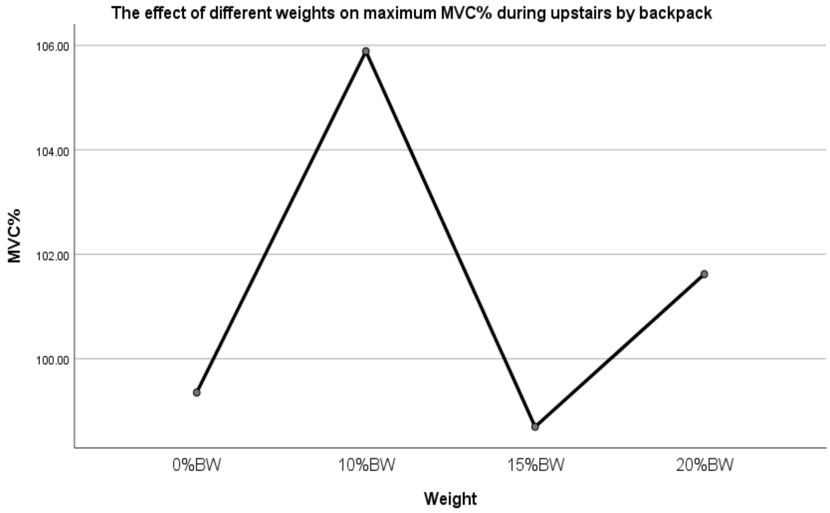
a. Computed using alpha = .05



Result of **left tibialis anterior muscle** during **upstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.879	421.188	1.293	.283	.051	2.430	.259

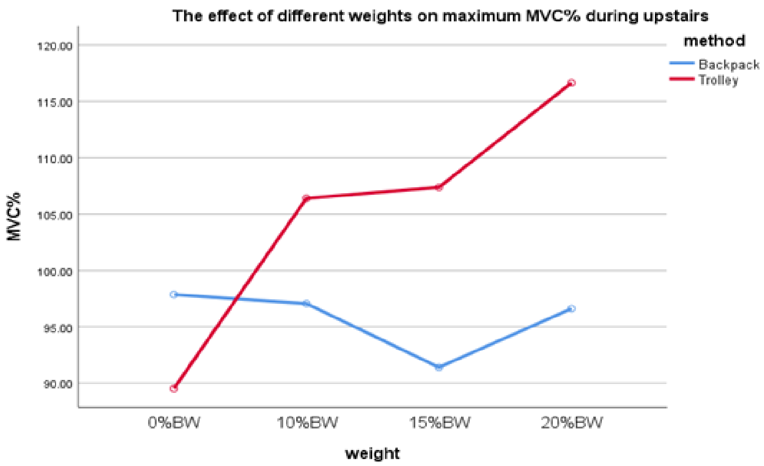
a. Computed using alpha = .05

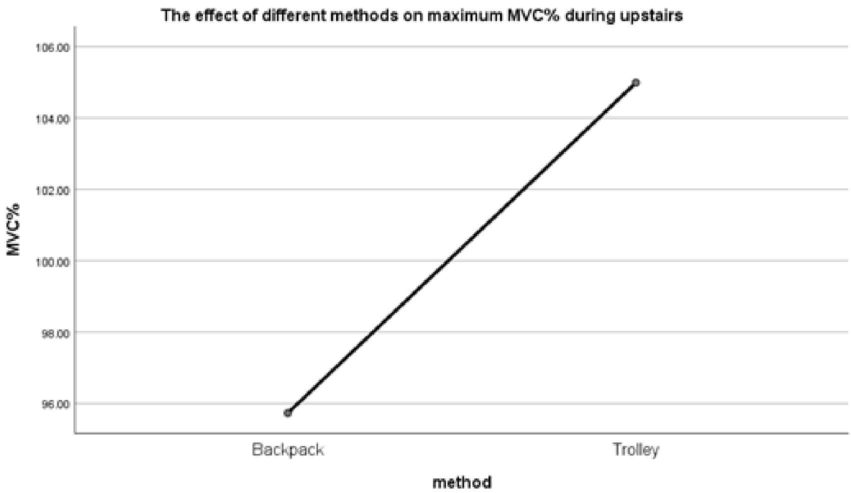


Result of **right tibialis anterior muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**4286.644**	**5.512**	**.027**	**.187**	**5.512**	**.615**
weight	2.170	1994.954	1.595	.211	.062	3.461	.336
method * weight	**2.134**	**2757.919**	**4.865**	**.010**	**.169**	**10.384**	**.797**

a. Computed using alpha = .05

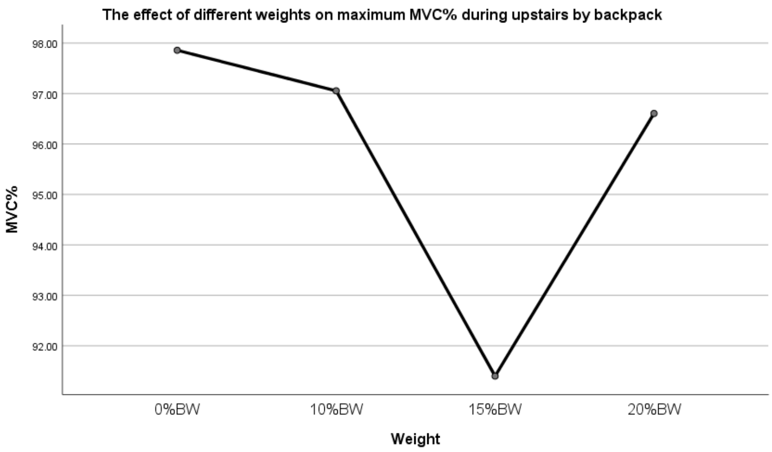




Result of **right tibialis anterior muscle** during **upstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	2.461	262.094	.920	.421	.037	2.265	.220

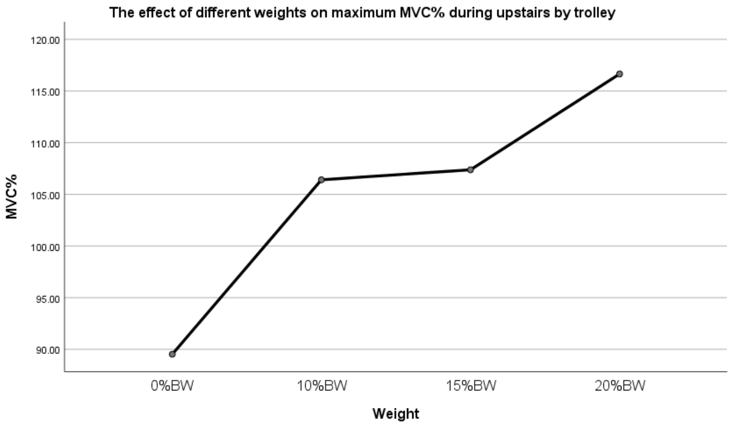
a. Computed using alpha = .05



Result of **right tibialis anterior muscle** during **upstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	2.139	4474.753	2.969	.057	.110	6.351	.571

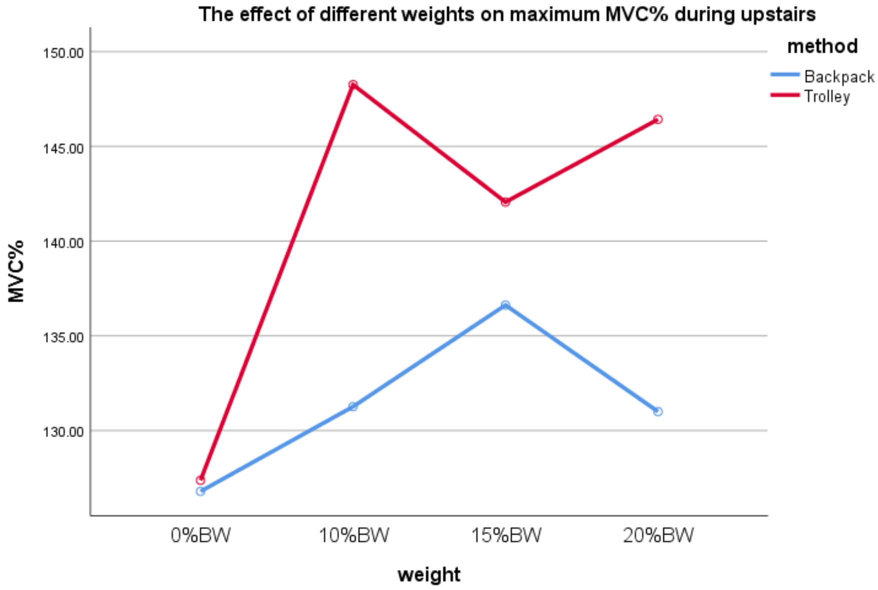
a. Computed using alpha = .05



Result of **left gastrocnemius muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	4616.426	3.681	.067	.133	3.681	.453
weight	2.038	2746.884	1.343	.271	.053	2.737	.278
method * weight	1.496	1563.306	.514	.550	.021	.769	.118

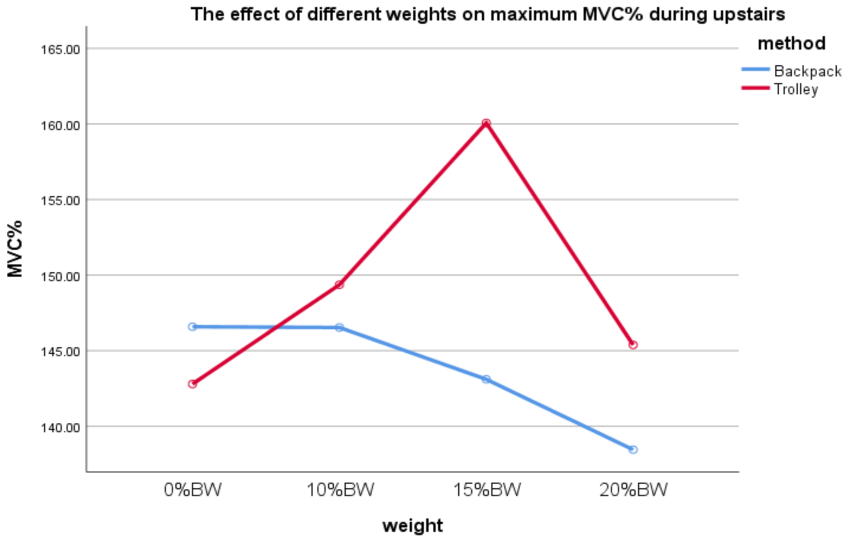
a. Computed using alpha = .05



Result of **right gastrocnemius muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	1643.178	2.604	.120	.098	2.604	.341
weight	3	870.445	.960	.416	.038	2.432	.231
method * weight	1.781	1589.822	2.476	.102	.094	4.409	.444

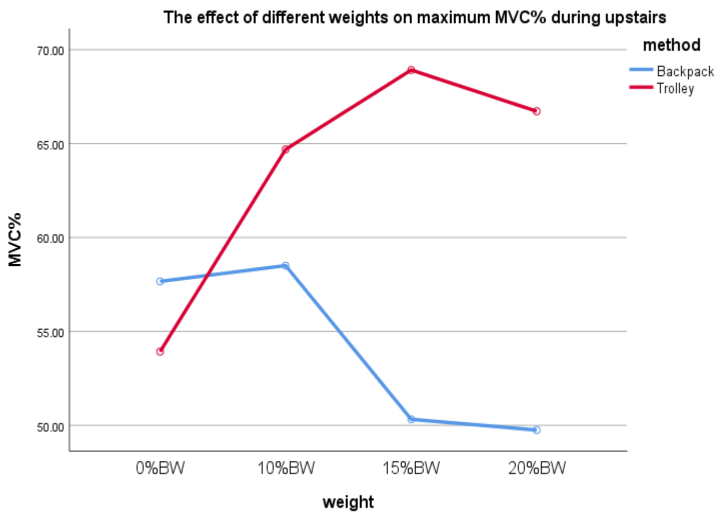
a. Computed using alpha = .05

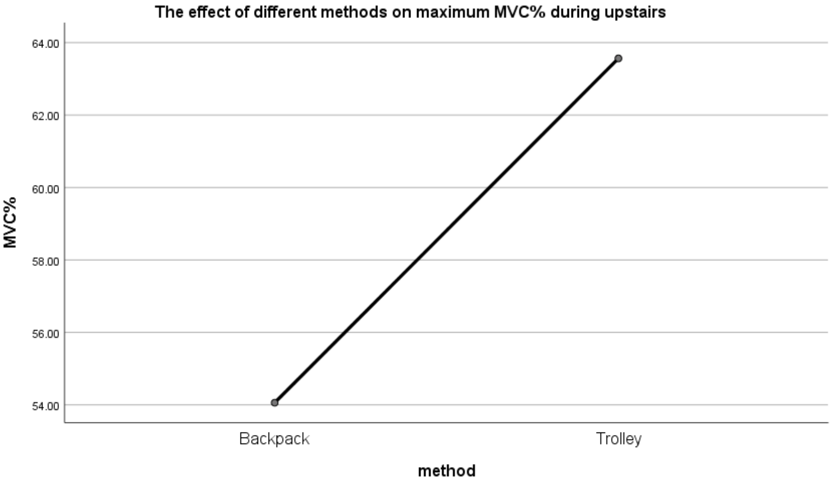


Result of **left semitendinosus muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**4518.096**	**23.209**	**.000**	**.492**	**23.209**	**.996**
weight	3	297.650	1.533	.213	.060	4.599	.388
method * weight	**2.289**	**1774.103**	**8.599**	**.000**	**.264**	**19.679**	**.974**

a. Computed using alpha = .05

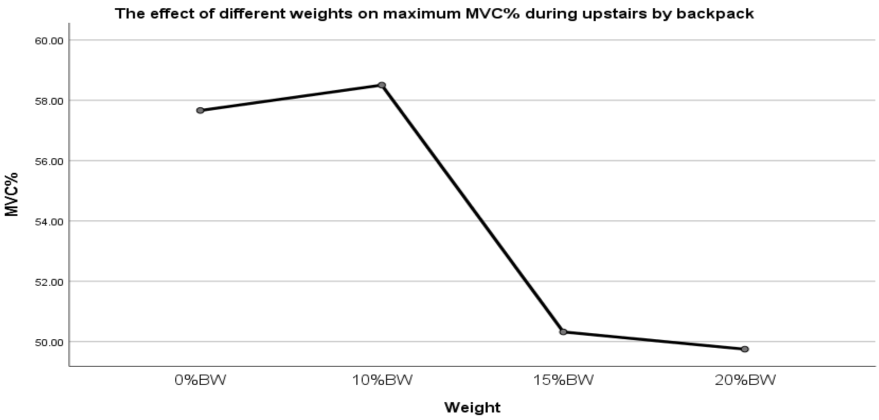




Result of **left semitendinosus muscle** during **upstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**3**	**544.147**	**12.760**	**.000**	**.347**	**38.281**	**1.000**

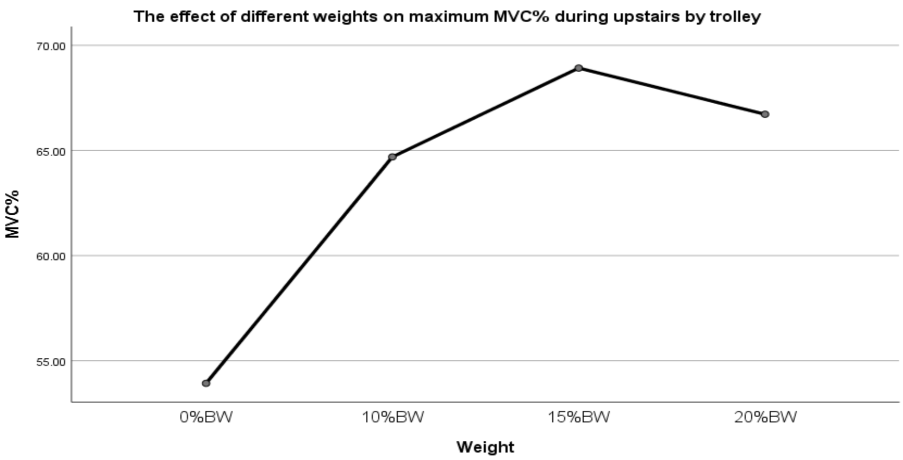
a. Computed using alpha = .05



Result of **left semitendinosus muscle** during **upstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**2.313**	**1435.861**	**3.583**	**.029**	**.130**	**8.287**	**.684**

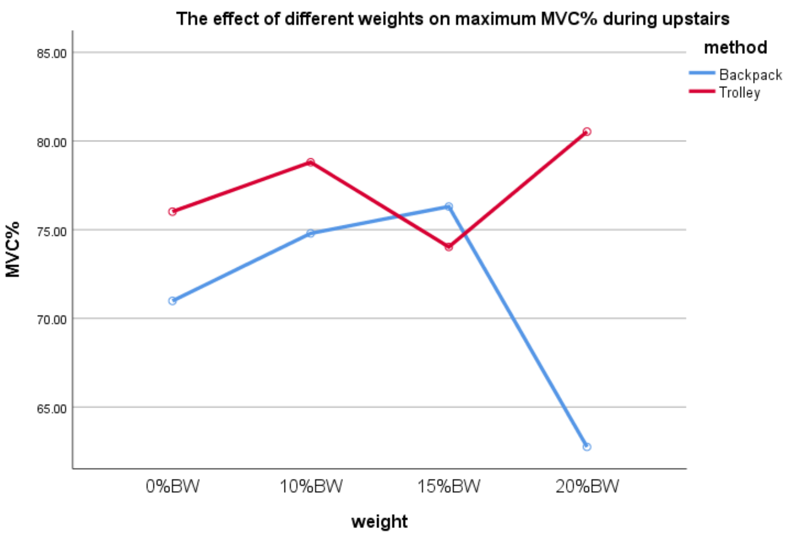
a. Computed using alpha = .05



Result of **right semitendinosus muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	1882.602	1.094	.306	.044	1.094	.171
weight	1.633	450.043	.320	.684	.013	.522	.093
method * weight	1.802	1470.882	1.645	.207	.064	2.964	.312

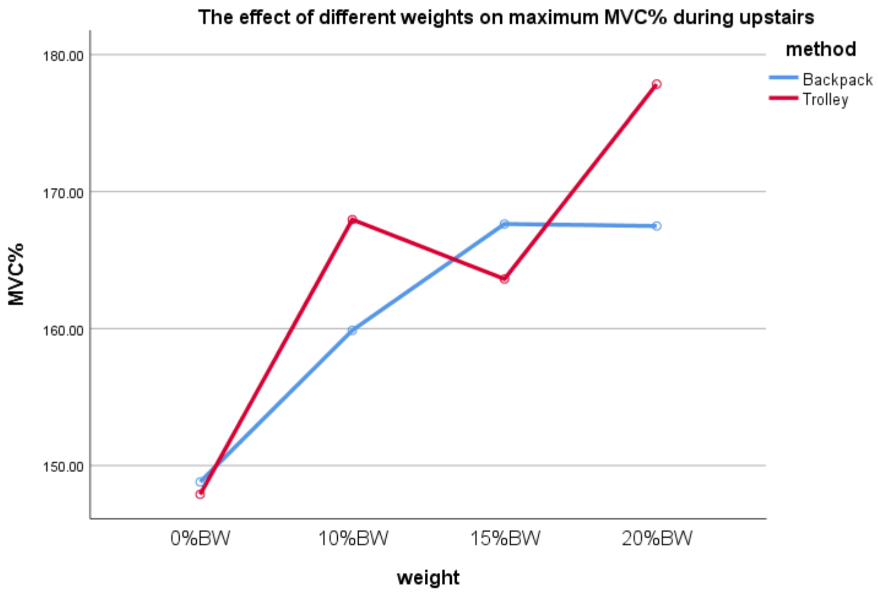
a. Computed using alpha = .05

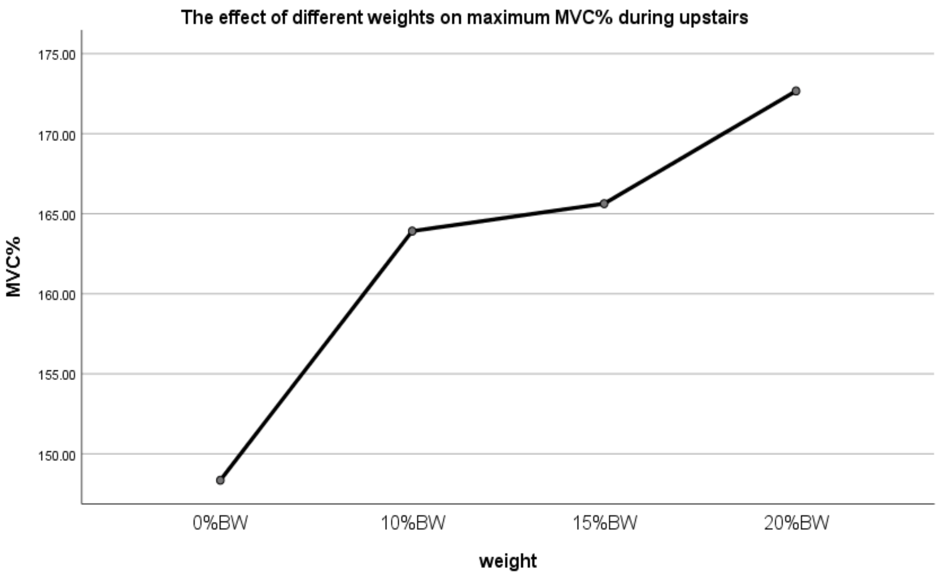


Result of **left rectus femoris muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	570.554	.267	.610	.011	.267	.079
weight	**2.213**	**7123.933**	**3.893**	**.023**	**.140**	**8.614**	**.709**
method * weight	3	600.077	.672	.572	.027	2.015	.185

a. Computed using alpha = .05

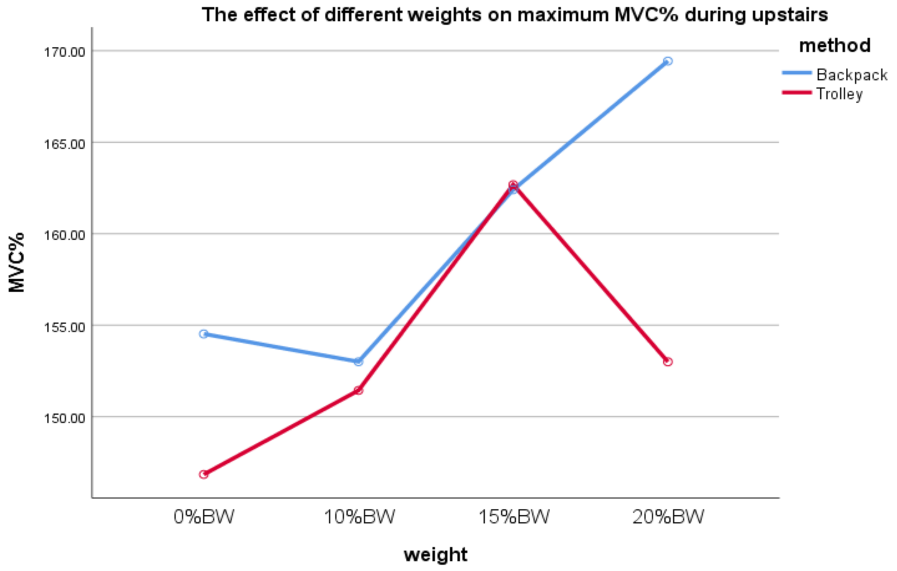




Result of **right rectus femoris muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	2018.832	.889	.355	.036	.889	.148
weight	2.051	2702.118	1.761	.182	.068	3.610	.356
method * weight	1.455	1463.224	.921	.379	.037	1.340	.175

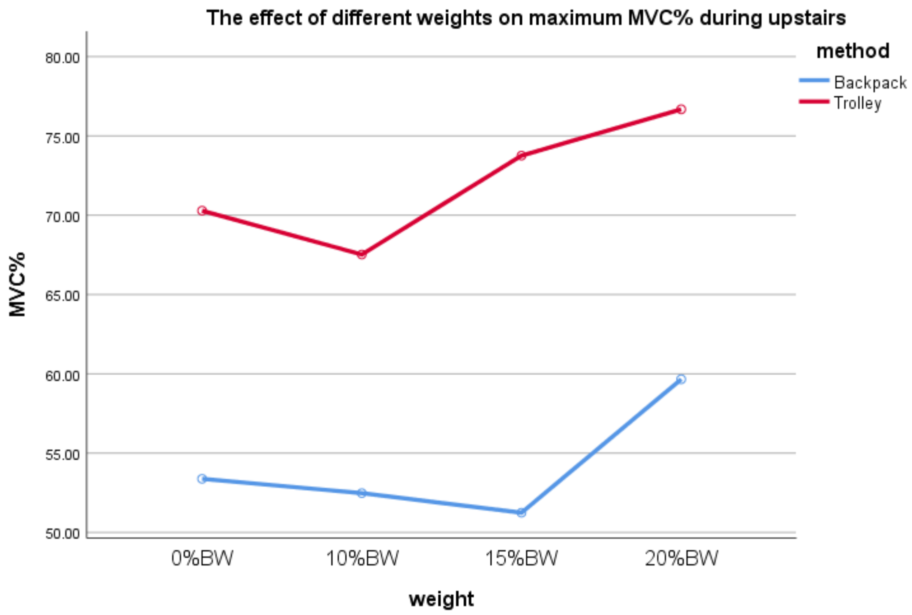
a. Computed using alpha = .05

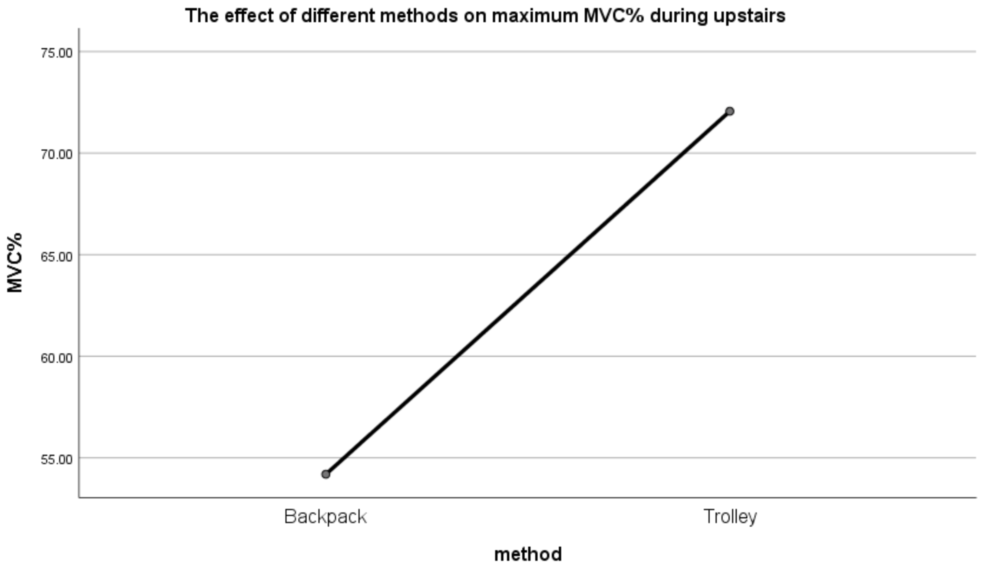


Result of **left lumbar erector spinae muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**15966.921**	**32.719**	**.000**	**.577**	**32.719**	**1.000**
weight	1.133	1643.747	.632	.453	.026	.716	.124
method * weight	1.218	320.271	.161	.741	.007	.196	.069

a. Computed using alpha = .05

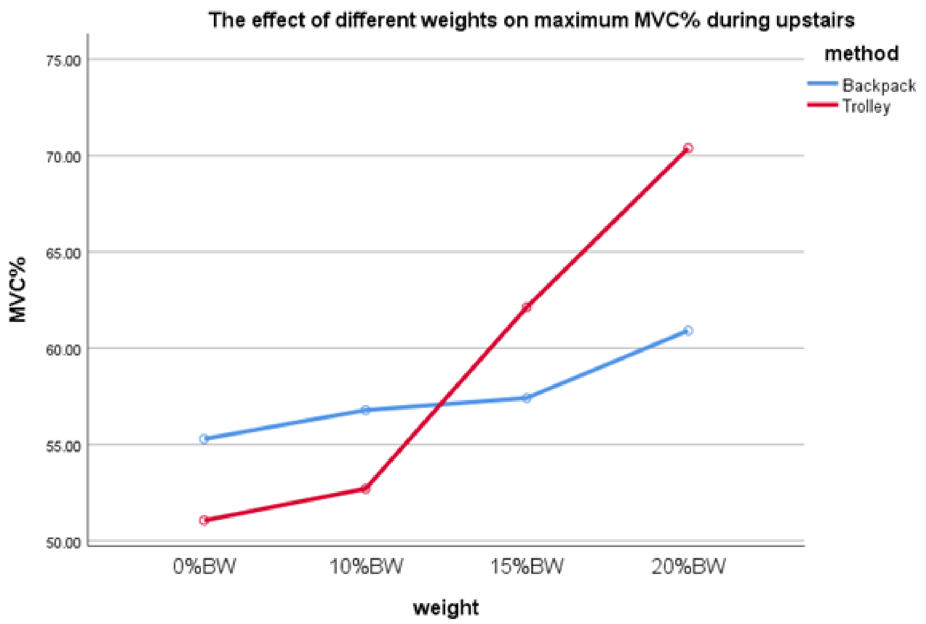


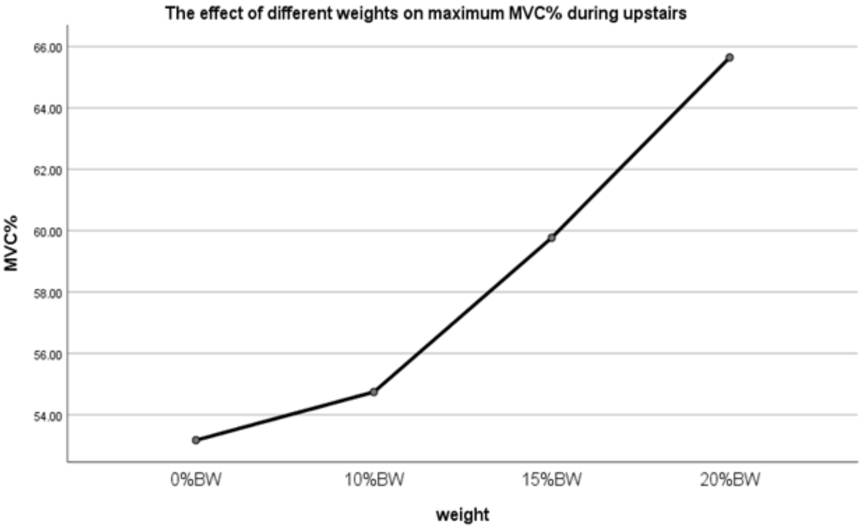


Result of **right lumbar erector spinae muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	107.687	.706	.409	.029	.706	.127
weight	**1.436**	**3312.515**	**6.522**	**.008**	**.214**	**9.366**	**.799**
method * weight	**1.466**	**1176.728**	**7.050**	**.006**	**.227**	**10.332**	**.836**

a. Computed using alpha = .05

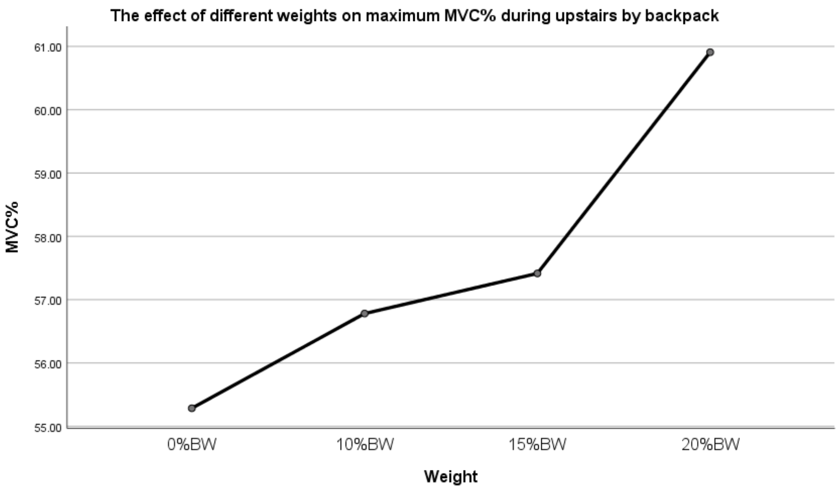




Result of **right lumbar erector spinae** muscle during **upstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.611	263.880	1.499	.236	.059	2.415	.272

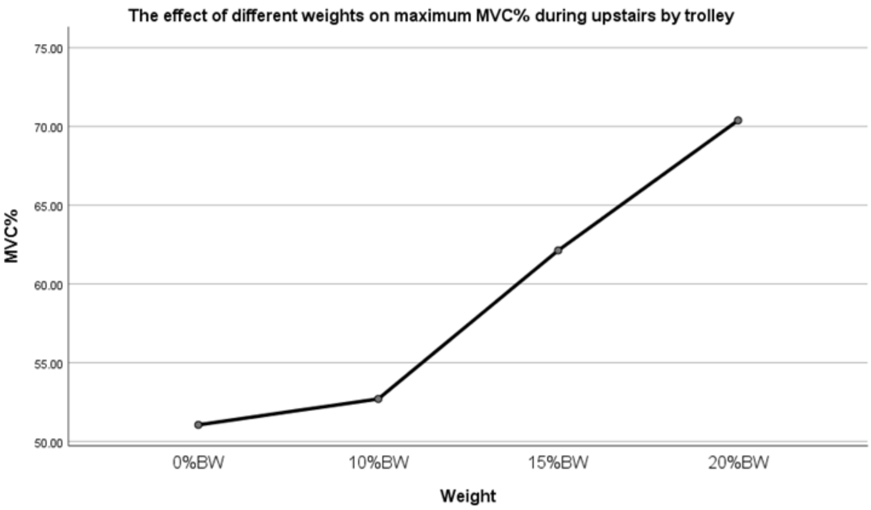
a. Computed using alpha = .05



Result of **right lumbar erector spinae** muscle during **upstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.414**	**4283.813**	**8.775**	**.002**	**.268**	**12.405**	**.900**

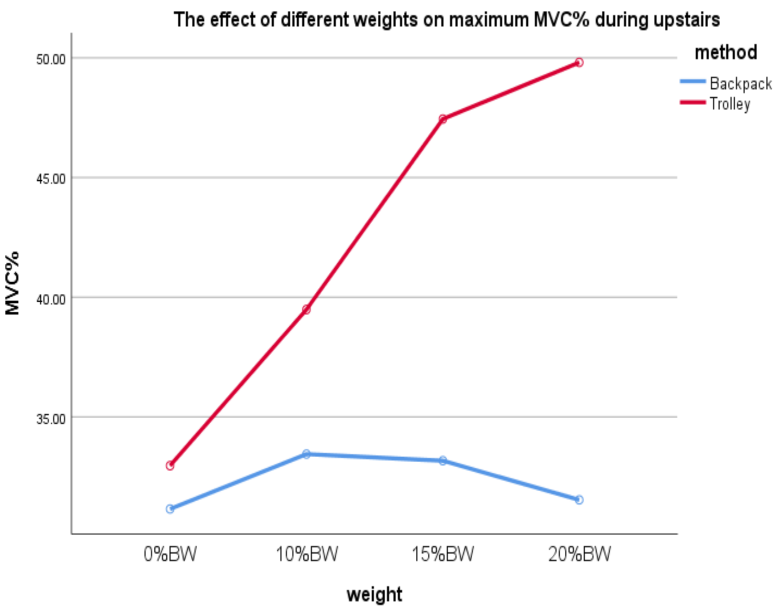
a. Computed using alpha = .05

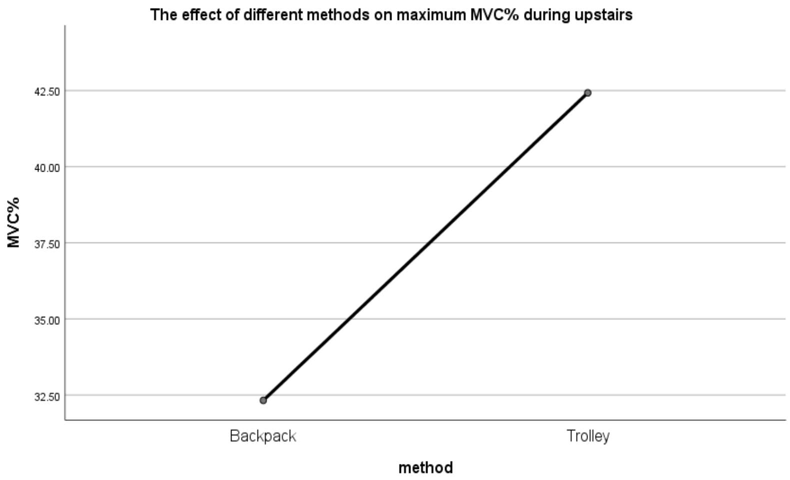


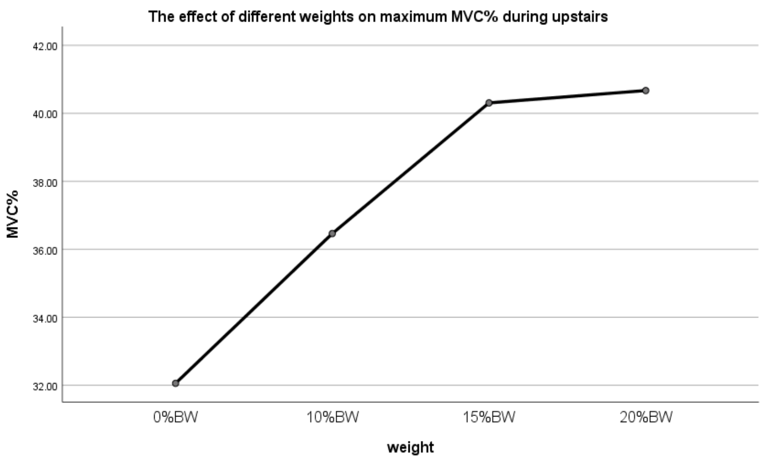
Result of **left abdominal muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**5102.582**	**16.510**	**.000**	**.408**	**16.510**	**.974**
weight	**1.529**	**1588.045**	**6.008**	**.010**	**.200**	**9.189**	**.784**
method * weight	**1.969**	**1076.208**	**5.949**	**.005**	**.199**	**11.713**	**.854**

a. Computed using alpha = .05



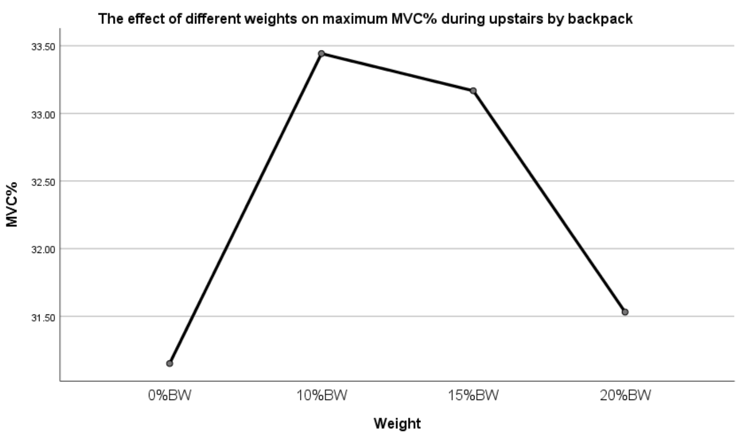




Result of **left abdominal muscle** during **upstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.595	62.171	.737	.456	.030	1.175	.154

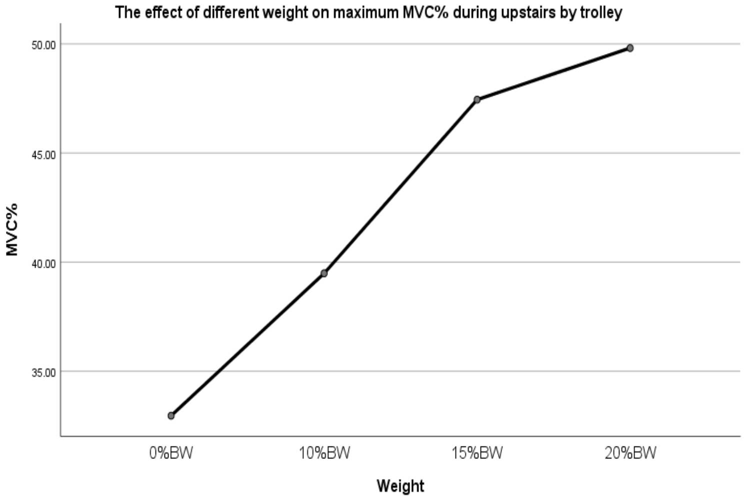
a. Computed using alpha = .05



Result of **left abdominal muscle** during **upstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.527**	**2912.653**	**7.108**	**.005**	**.228**	**10.855**	**.850**

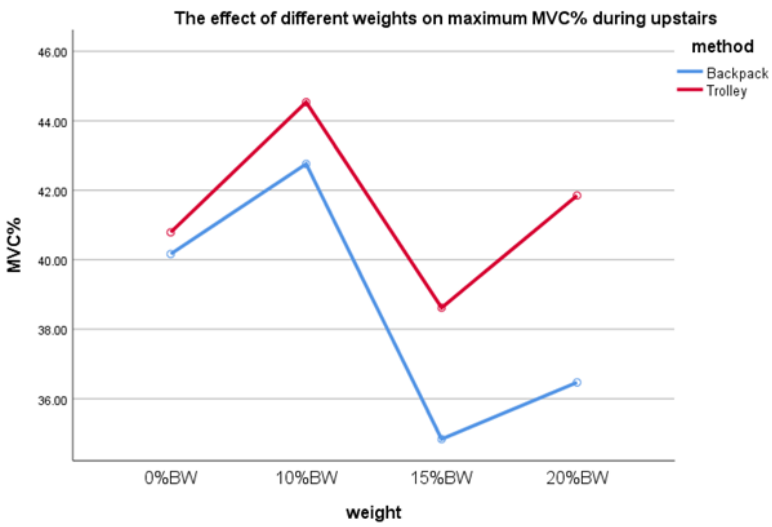
a. Computed using alpha = .05

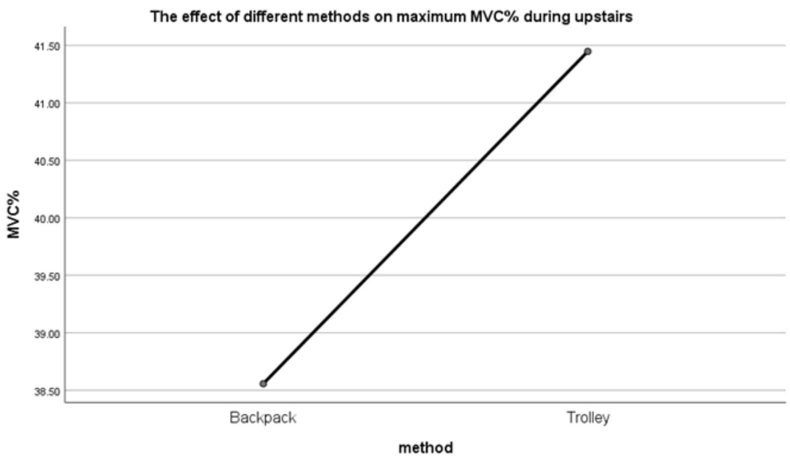


Result of **right abdominal muscle** during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**417.708**	**5.114**	**.033**	**.176**	**5.114**	**.583**
weight	1.028	1213.120	.446	.516	.018	.459	.099
method * weight	3	55.690	2.474	.068	.093	7.422	.592

a. Computed using alpha = .05

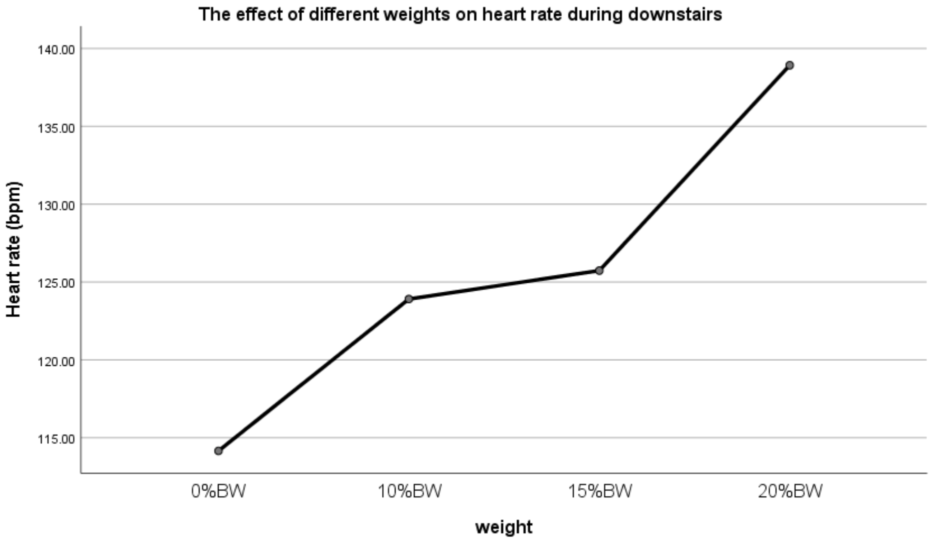




Result of **heart rate** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	318.214	.828	.372	.033	.828	.141
weight	**3**	**5190.054**	**17.637**	**.000**	**.424**	**50.244**	**1.000**
method * weight	3	420.065	1.612	.194	.063	4.837	.407

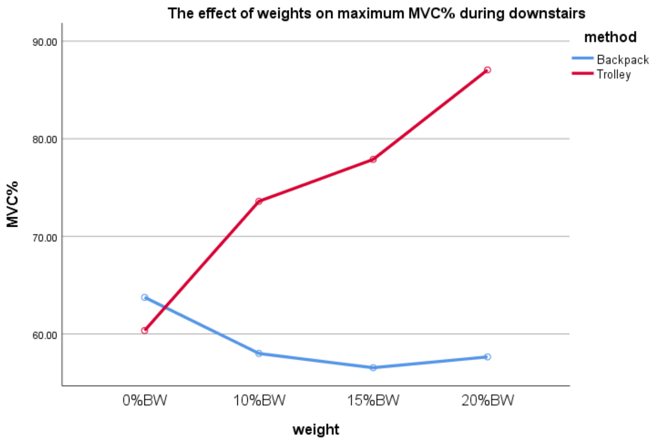
a. Computed using alpha = .05

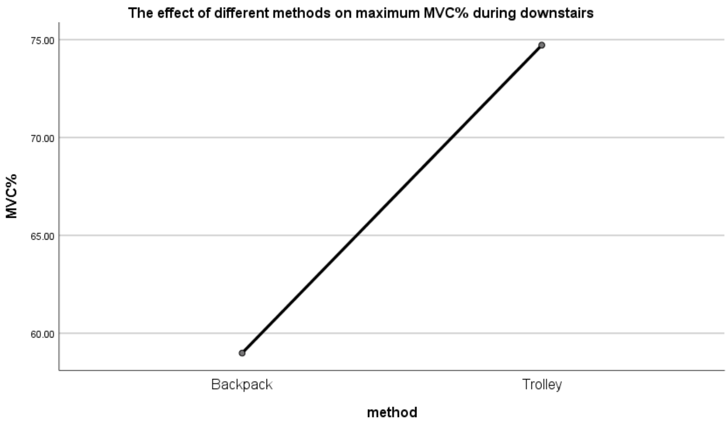


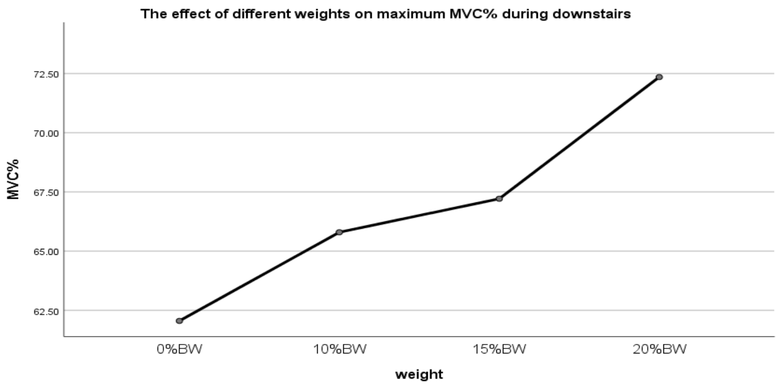
Result of **left tibialis anterior muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**12373.786**	**29.755**	**.000**	**.0554**	**29.755**	**.999**
weight	**1.742**	**1565.072**	**4.501**	**.021**	**.158**	**7.839**	**.698**
method * weight	**3**	**2433.541**	**17.872**	**.000**	**.427**	**53.617**	**1.000**

a. Computed using alpha = .05



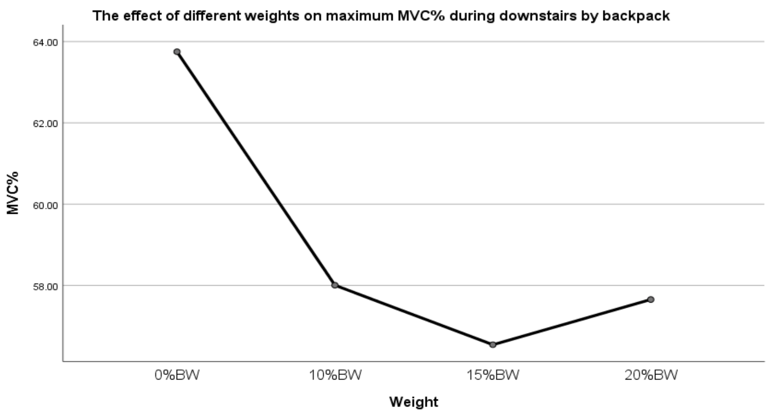




Result of **left tibialis anterior muscle** during **downstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.525**	**515.030**	**3.624**	**.048**	**.131**	**5.527**	**.559**

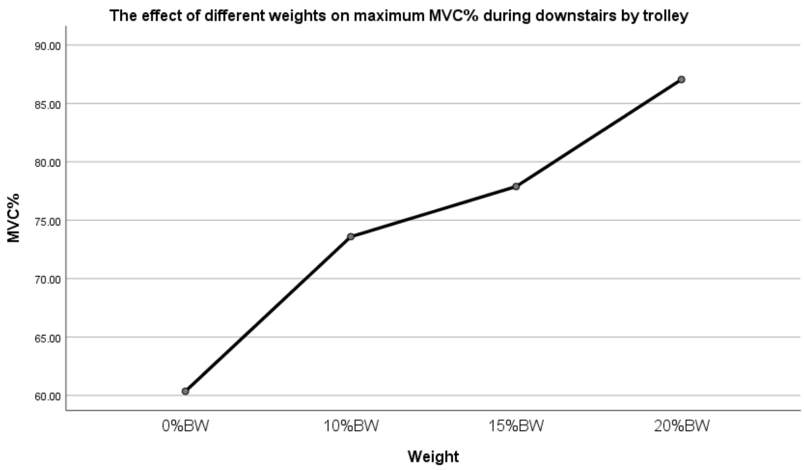
a. Computed using alpha = .05



Result of **left tibialis anterior muscle** during **downstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**2.122**	**4354.550**	**11.588**	**.000**	**.326**	**24.593**	**.993**

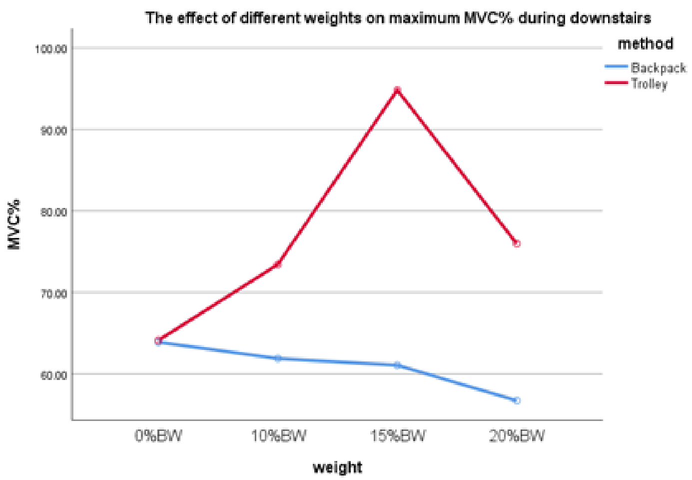
a. Computed using alpha = .05

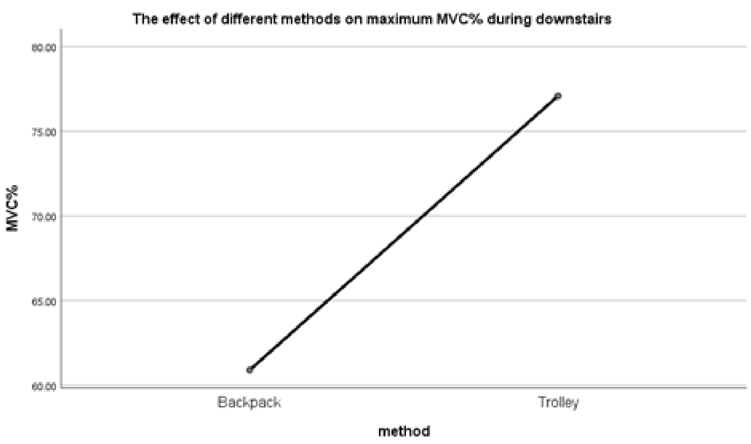


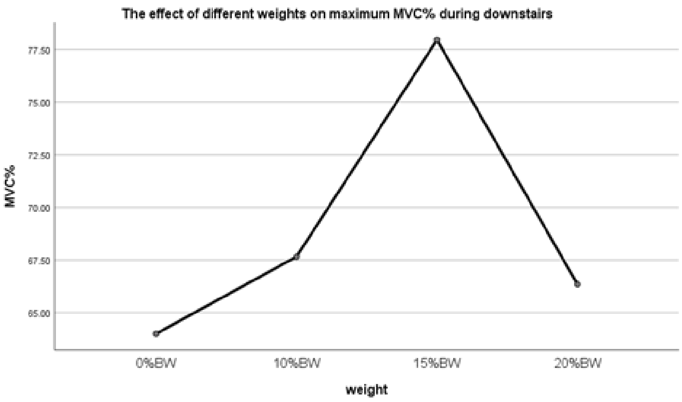
Result of **right tibialis anterior muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**13113.795**	**32.485**	**.000**	**.575**	**32.485**	**1.000**
weight	**1.967**	**2896.313**	**4.858**	**.012**	**.168**	**9.555**	**.771**
method * weight	**1.722**	**4320.469**	**8.608**	**.001**	**.264**	**14.825**	**.935**

a. Computed using alpha = .05



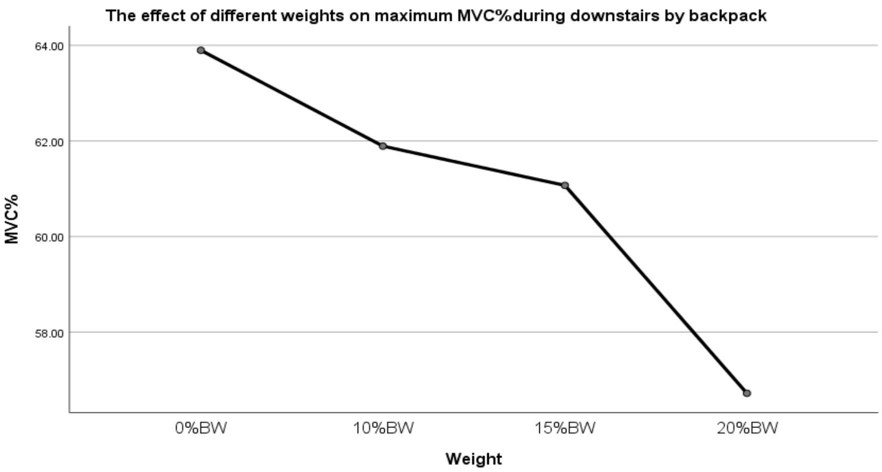




Result of **right tibialis anterior muscle** during **downstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	3	228.782	2.084	.110	.080	6.252	.512

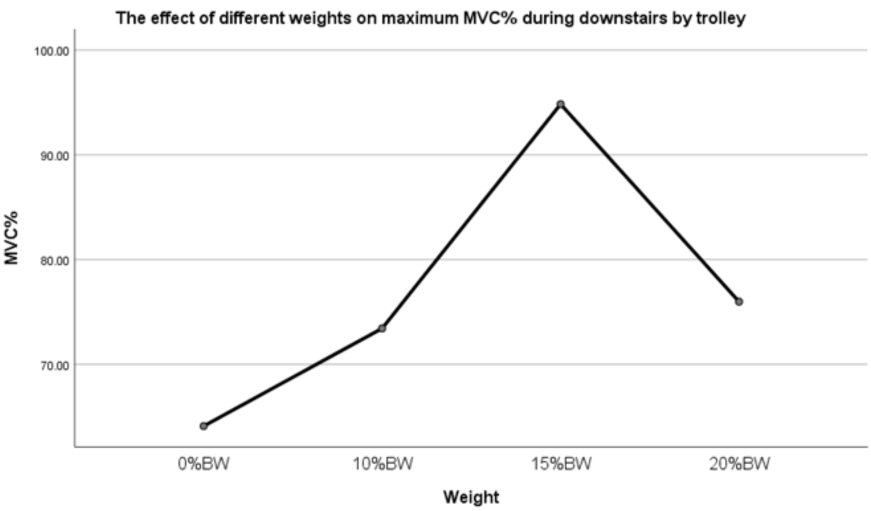
a. Computed using alpha = .05



Result of **right tibialis anterior muscle** during **downstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.670**	**7453.928**	**7.291**	**.003**	**.233**	**12.179**	**.882**

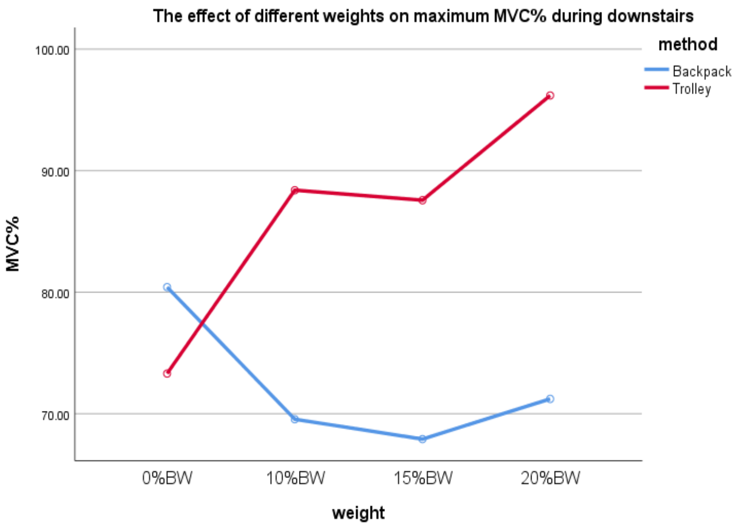
a. Computed using alpha = .05

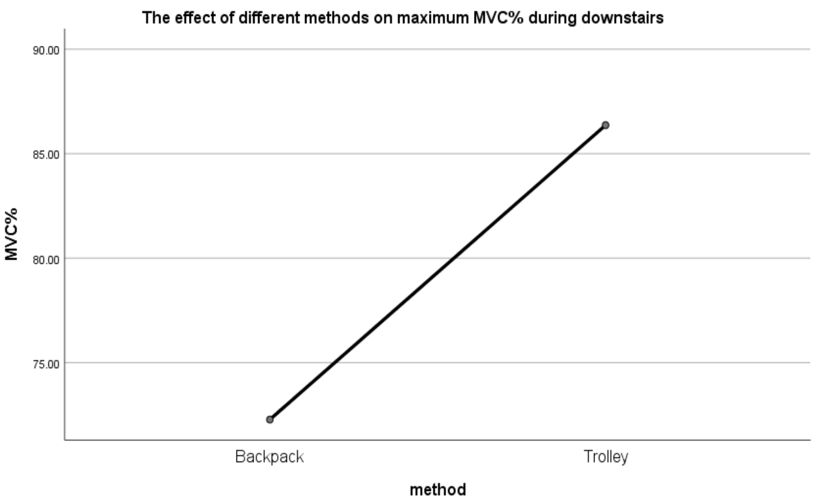


Result of **left gastrocnemius muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**9926.899**	**12.043**	**.002**	**.334**	**12.043**	**.914**
weight	2.253	618.363	1.112	.342	.044	2.506	.248
method * weight	**1.508**	**5151.104**	**4.602**	**.025**	**.161**	**6.942**	**.662**

a. Computed using alpha = .05

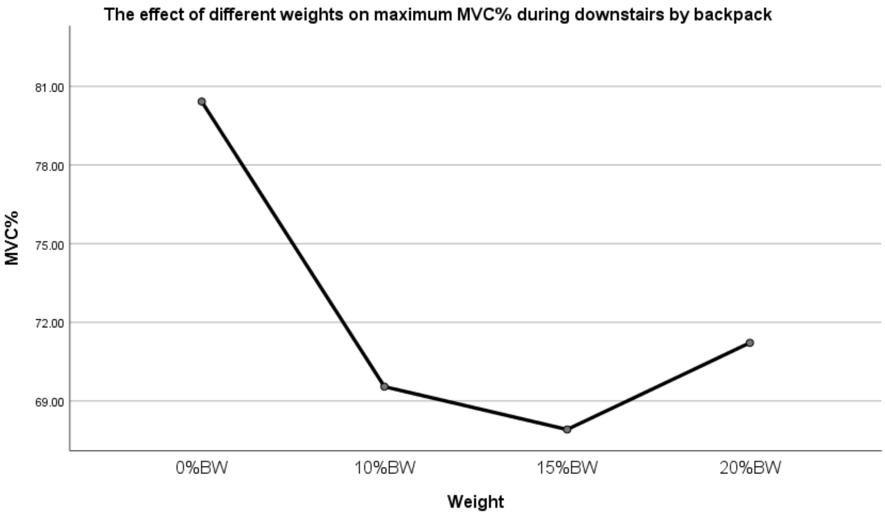




Result of **left gastrocnemius muscle** during **downstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.597	1470.263	2.924	.077	.109	4.672	.482

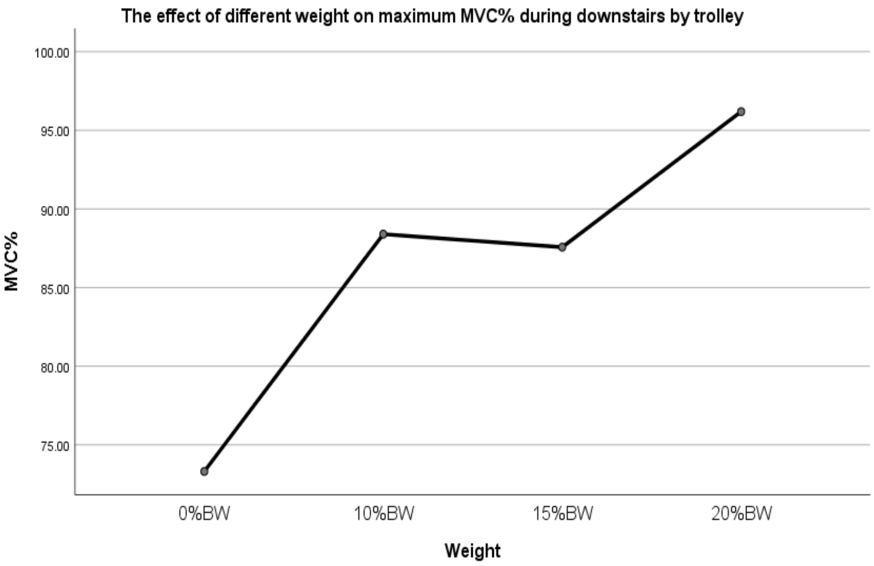
a. Computed using alpha = .05



Result of **left gastrocnemius muscle** during **downstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**3**	**2271.470**	**3.188**	**.029**	**.117**	**9.563**	**.714**

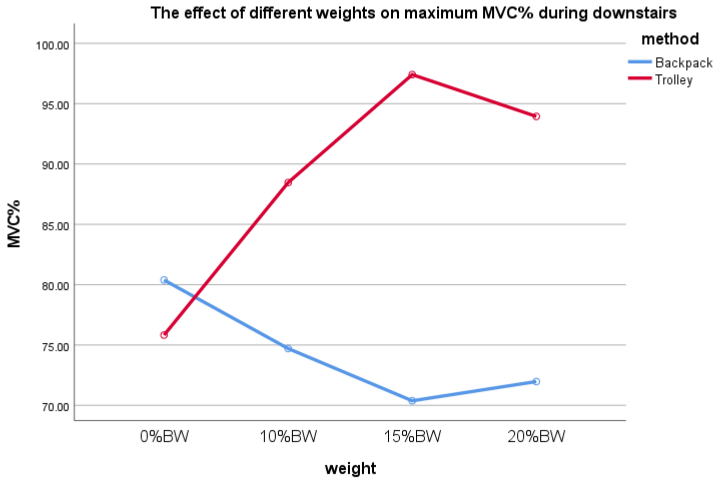
a. Computed using alpha = .05

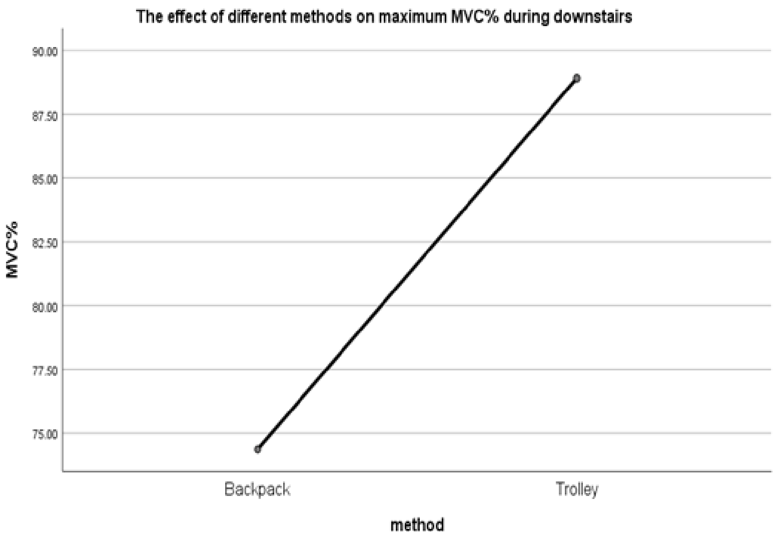


Result of **right gastrocnemius muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**10582.735**	**24.436**	**.000**	**.505**	**24.436**	**.997**
weight	3	322.034	1.770	.161	.069	5.310	.384
method * weight	**3**	**2402.998**	**15.397**	**.000**	**.391**	**46.191**	**1.000**

a. Computed using alpha = .05

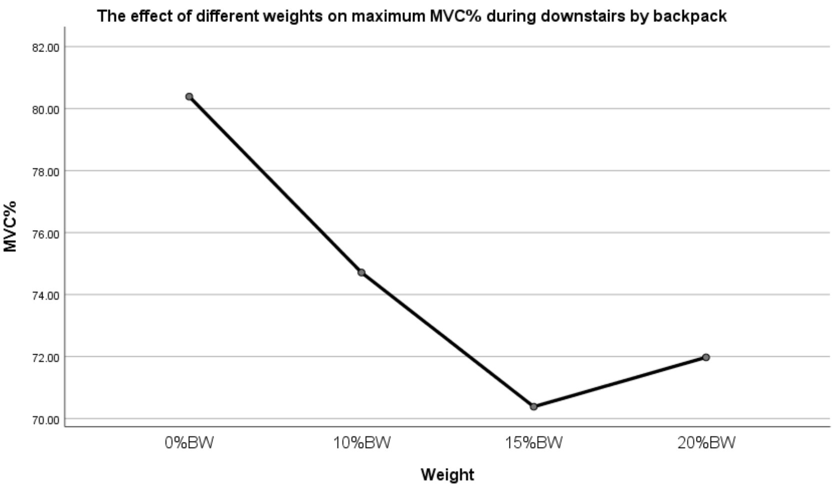




Result of **right gastrocnemius muscle** during **downstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.890	766.865	2.948	.065	.109	5.572	.531

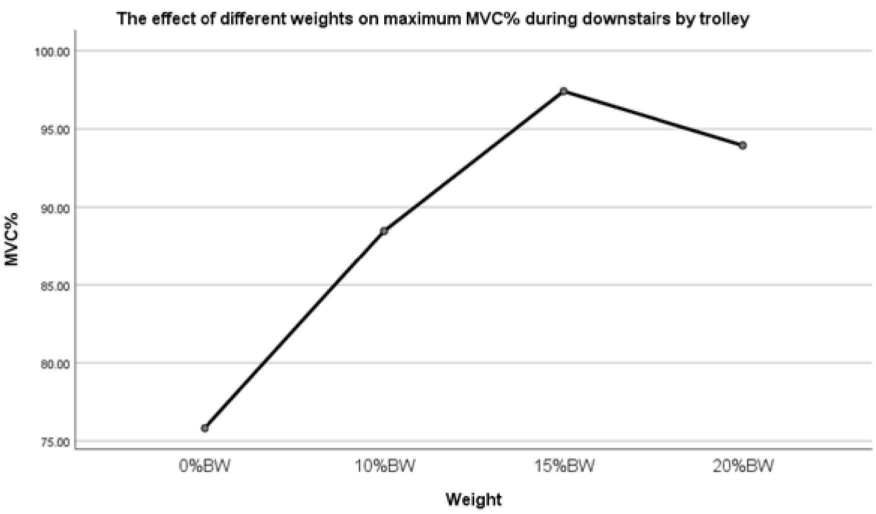
a. Computed using alpha = .05



Result of **right gastrocnemius muscle** during **downstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**3**	**2241.923**	**12.875**	**.000**	**.349**	**38.625**	**1.000**

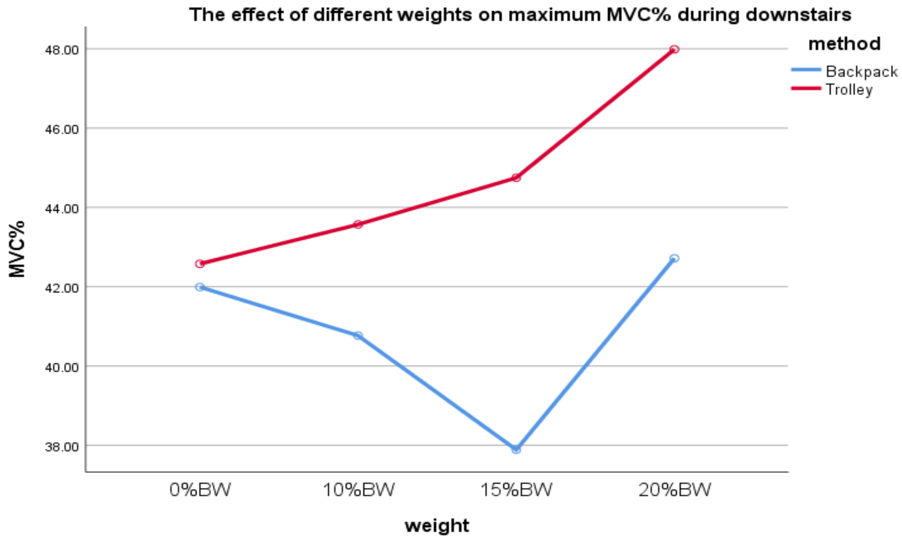
a. Computed using alpha = .05



Result of **left semitendinosus muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	752.383	3.284	.083	.120	3.284	.413
weight	1.718	272.982	1.133	.325	.045	1.946	.221
method * weight	1.678	169.956	.779	.445	.031	1.307	.163

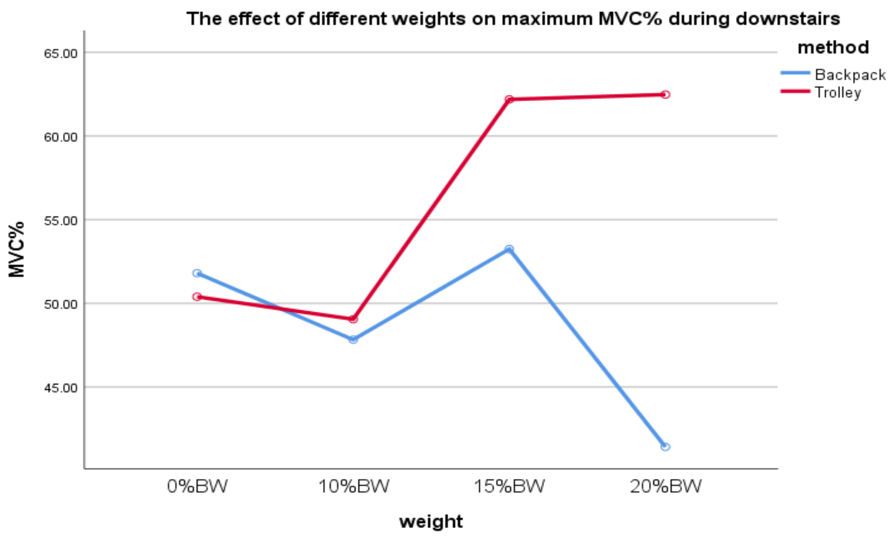
a. Computed using alpha = .05



Result of **right semitendinosus muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	2777.951	1.717	.202	.067	1.717	.242
weight	1.424	1608.481	.447	.577	.018	.637	.108
method * weight	1.739	2190.458	1.414	.254	.056	2.459	.269

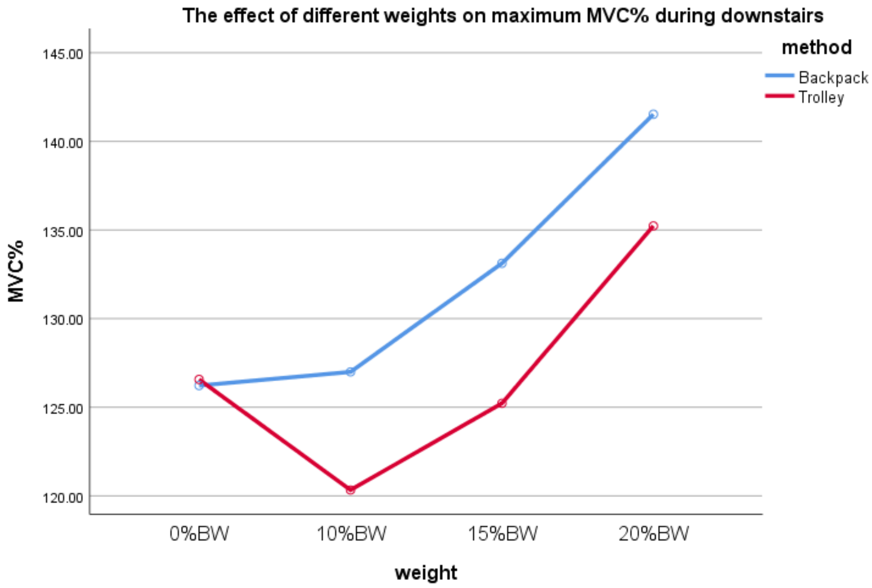
a. Computed using alpha = .05



Result of **left rectus femoris muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	1315.311	1.280	.269	.051	1.280	.192
weight	1.861	3295.454	2.417	.104	.091	4.497	.446
method * weight	3	172.337	.315	.814	.013	.946	.108

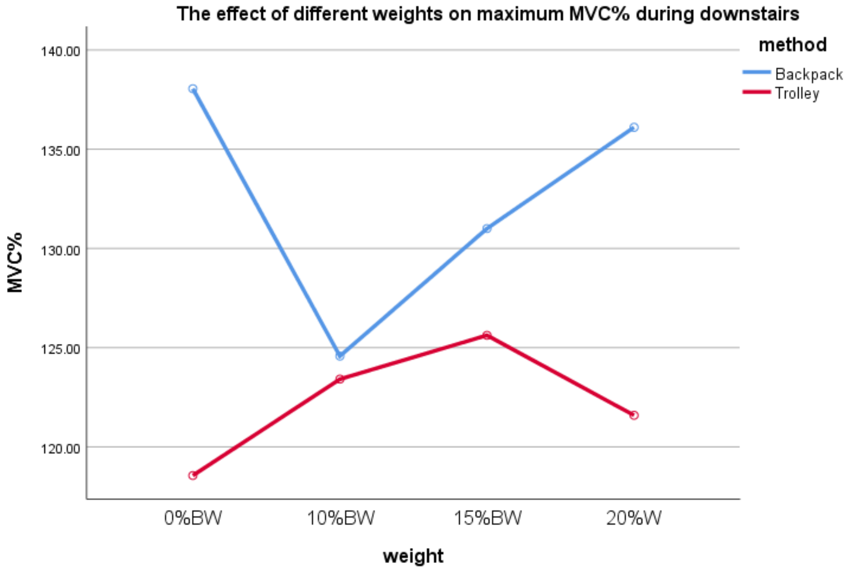
a. Computed using alpha = .05

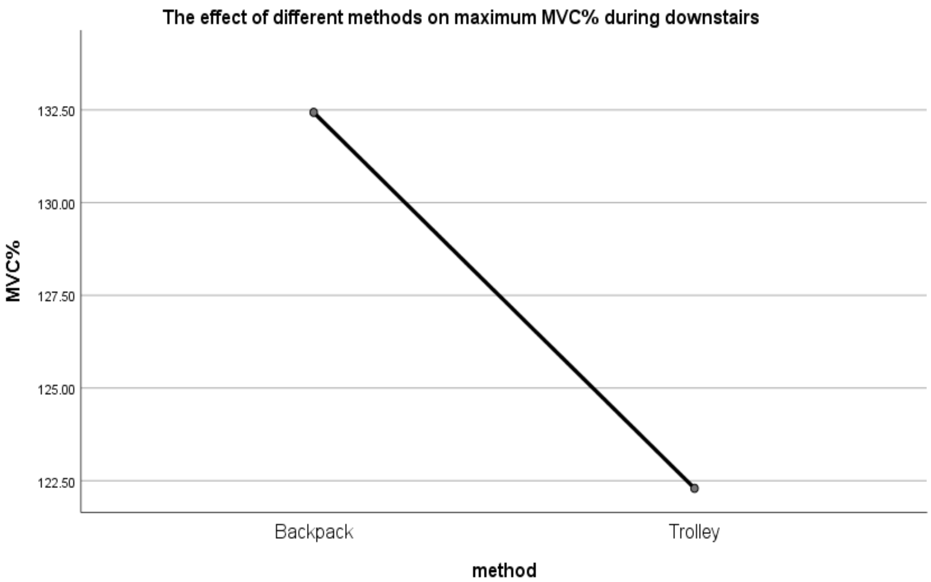


Result of **right rectus femoris muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**5138.173**	**5.454**	**.028**	**.185**	**5.454**	**.611**
weight	1.745	439.266	.292	.719	.012	.510	.091
method * weight	2.106	1245.609	1.149	.327	.046	2.419	.247

a. Computed using alpha = .05

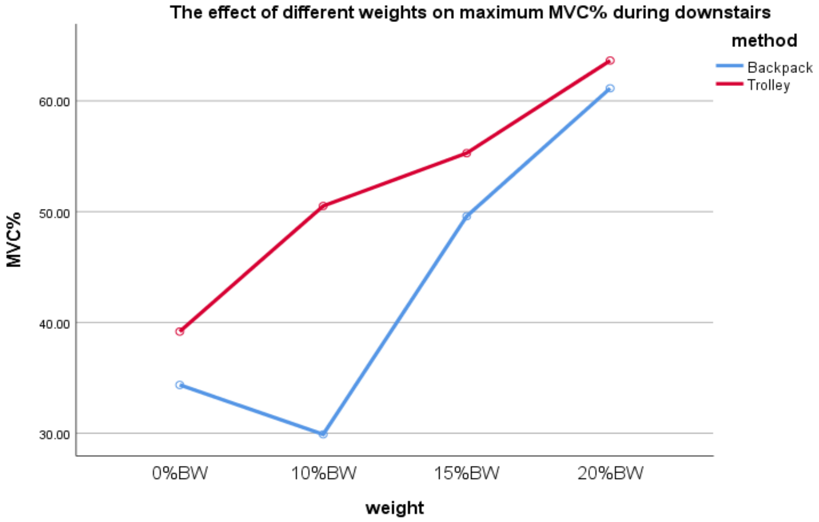


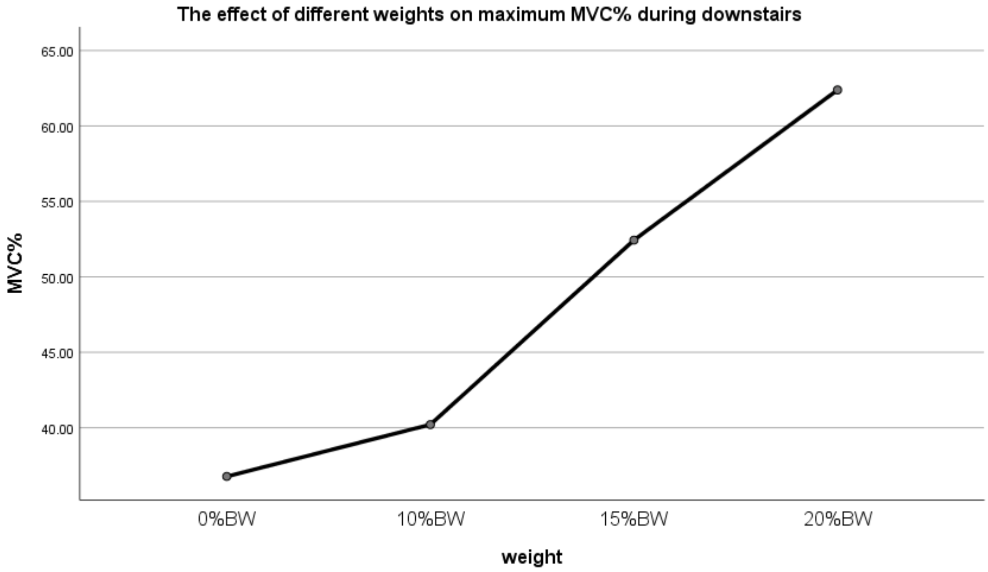


Result of **left lumbar erector spinae muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	3534.725	1.432	.243	.056	1.432	.210
weight	**1.932**	**10698.257**	**4.579**	**.016**	**.160**	**8.848**	**.739**
method * weight	1.557	1638.648	.651	.490	.026	1.014	.140

a. Computed using alpha = .05

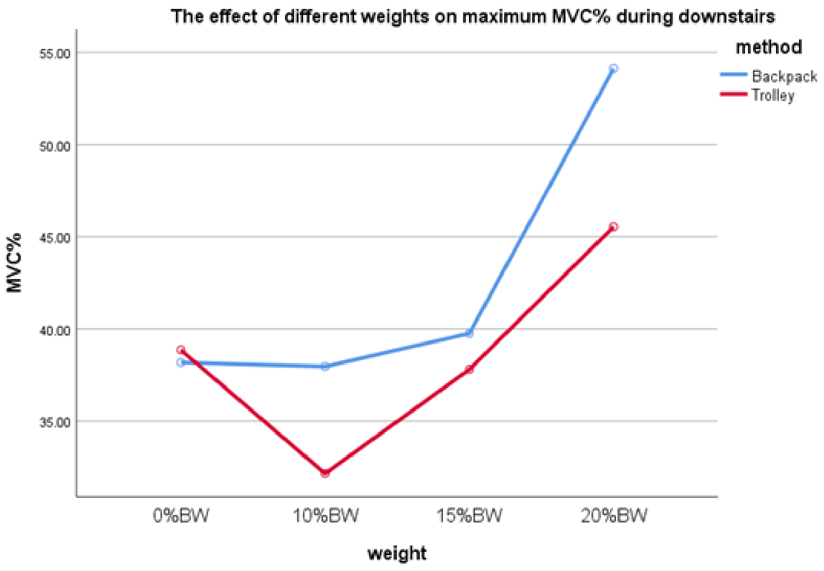




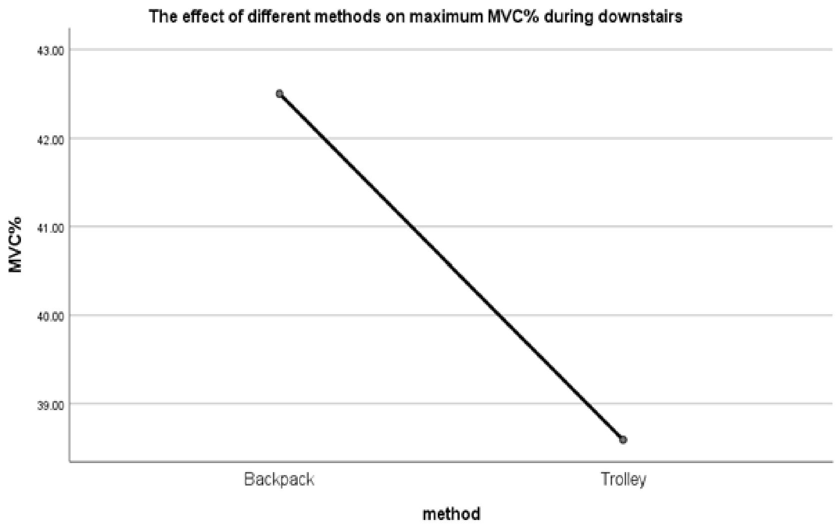
Result of **right lumbar erector spinae muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**766.491**	**4.422**	**.046**	**.156**	**4.422**	**.523**
weight	**1.601**	**3861.007**	**6.083**	**.008**	**.202**	**9.741**	**.803**
method * weight	2.073	304.200	1.512	.230	.059	3.134	.312

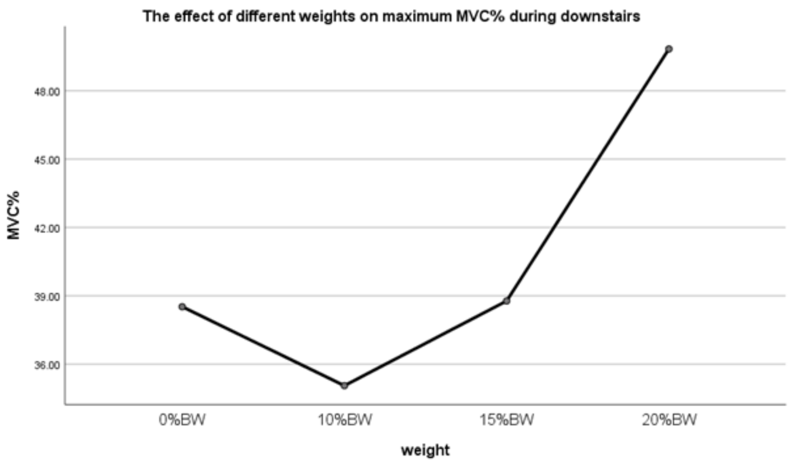
a. Computed using alpha = .05



The effect of different weights on maximum MVC% during downstairs
method
Backpack
Trolley
55.00
50.00
45.00
40.00
35.00
MVC%
0%BW
10%BW
15%BW
20%BW
weight



The effect of different methods on maximum MVC% during downstairs
43.00
42.00
41.00
40.00
39.00
MVC%
Backpack
Trolley
method

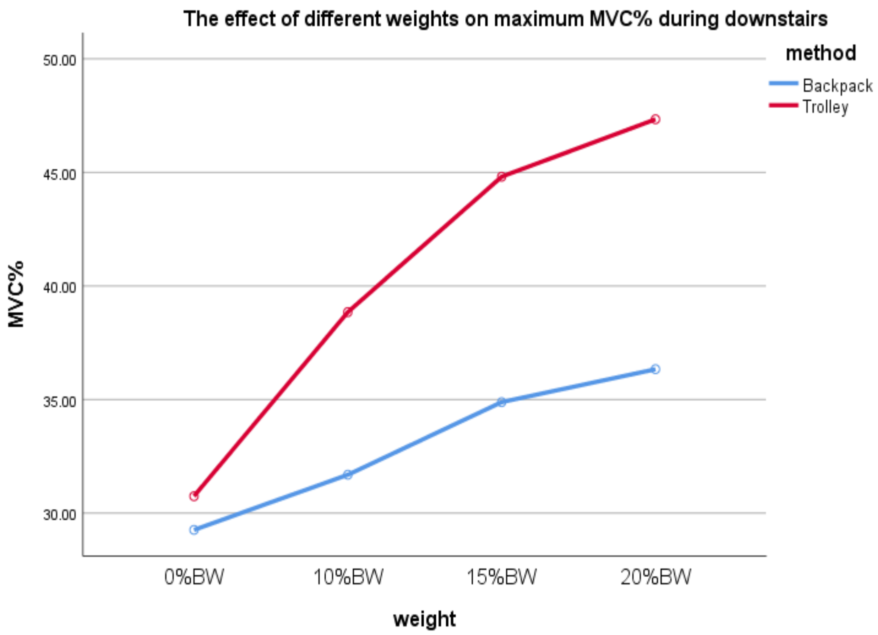


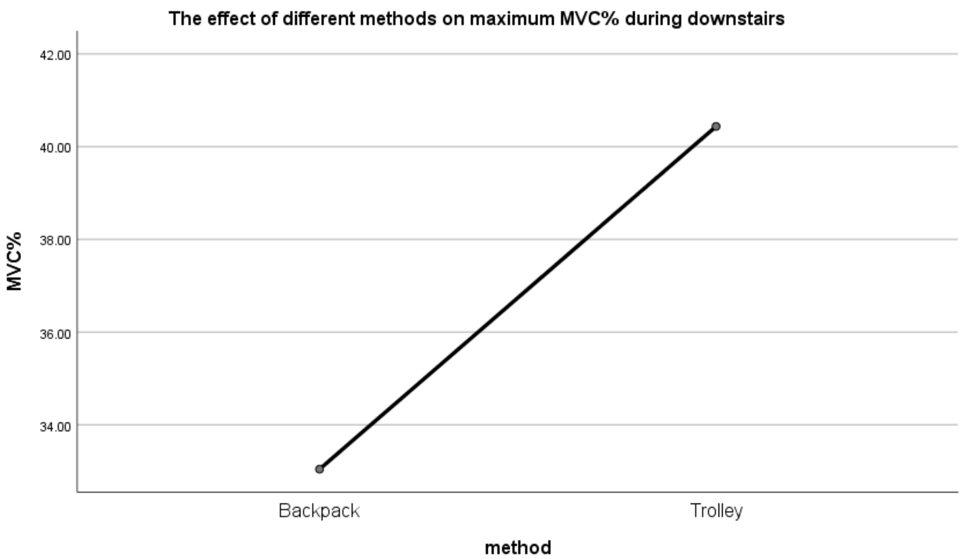
The effect of different weights on maximum MVC% during downstairs
48.00
45.00
42.00
39.00
36.00
MVC%
0%BW
10%BW
15%BW
20%BW
weight

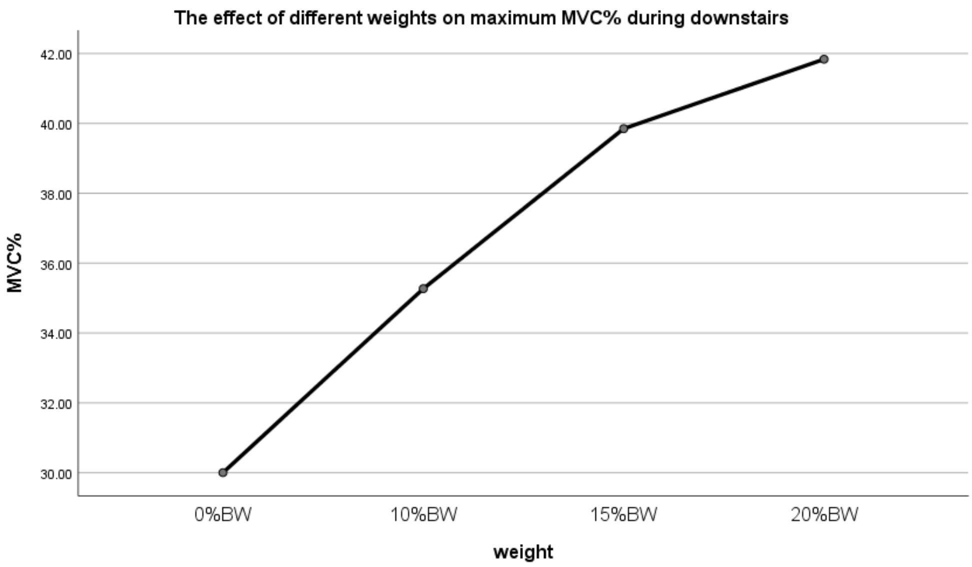
Result of **left abdominal muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**2732.950**	**7.073**	**.014**	**.228**	**7.073**	**.723**
weight	**1.559**	**2668.986**	**10.424**	**.001**	**.303**	**16.246**	**.958**
method * weight	1.163	584.485	1.095	.315	.044	1.273	.182

a. Computed using alpha = .05



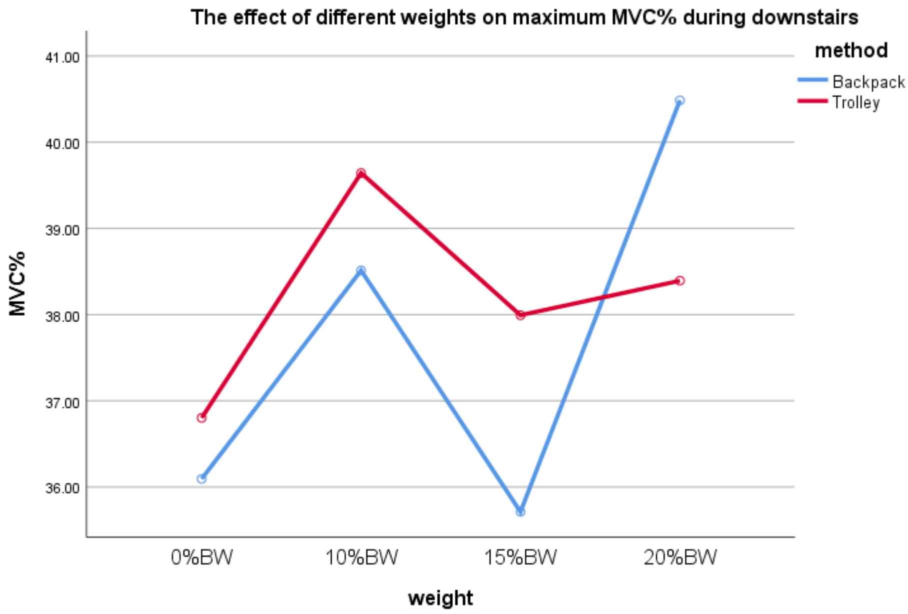




Result of **right abdominal muscle** during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	12.821	.157	.695	.007	.157	.067
weight	1.777	295.272	.257	.654	.011	.303	.080
method * weight	1.902	67.942	.556	.569	.023	1.056	.134

a. Computed using alpha = .05

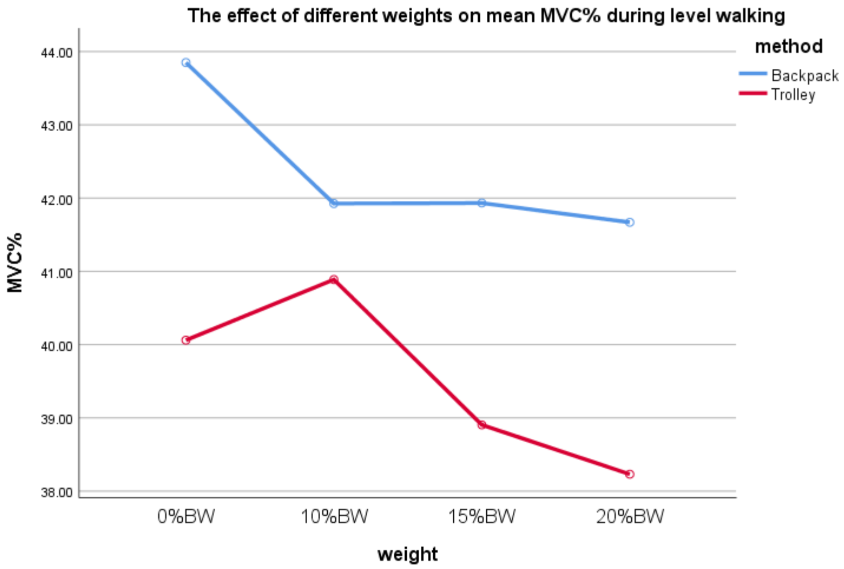


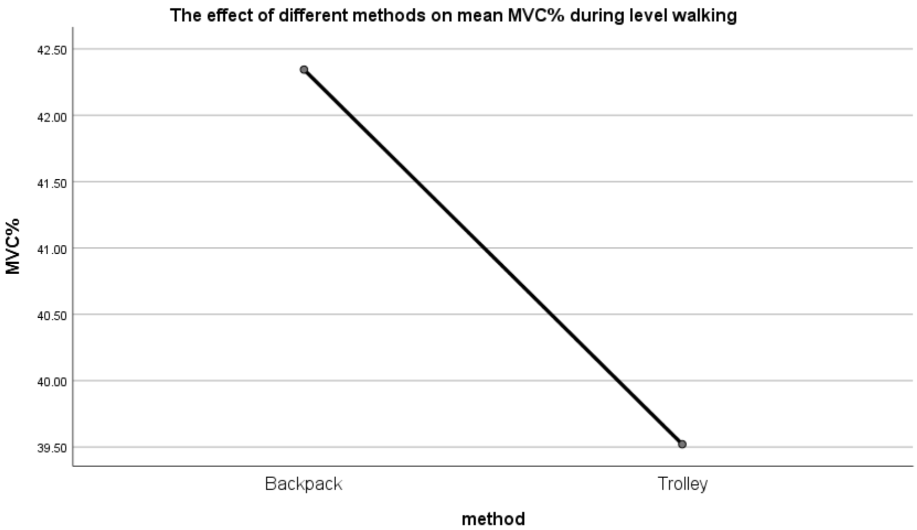
Results of mean MVC%

Result of **left tibialis anterior muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**398.533**	**17.230**	**.000**	**.418**	**17.230**	**.978**
weight	1.604	77.952	1.005	.360	.040	1.612	.195
method * weight	3	18.915	1.212	.312	.048	3.636	.312

a. Computed using alpha = .05

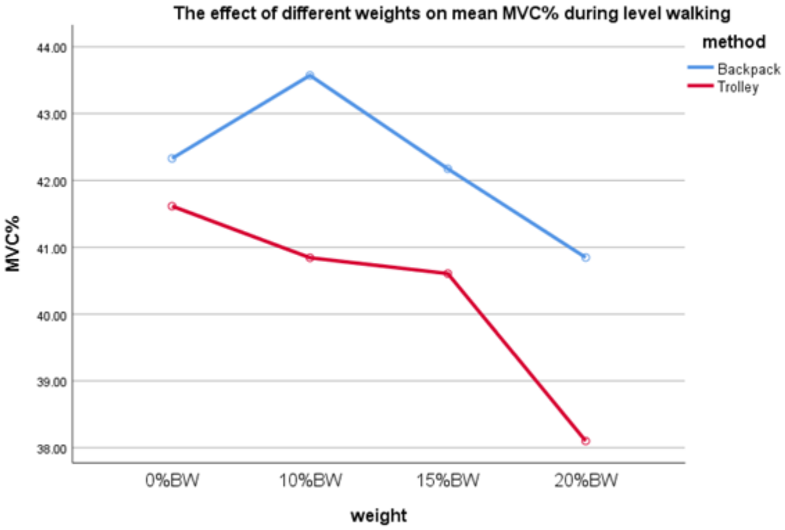


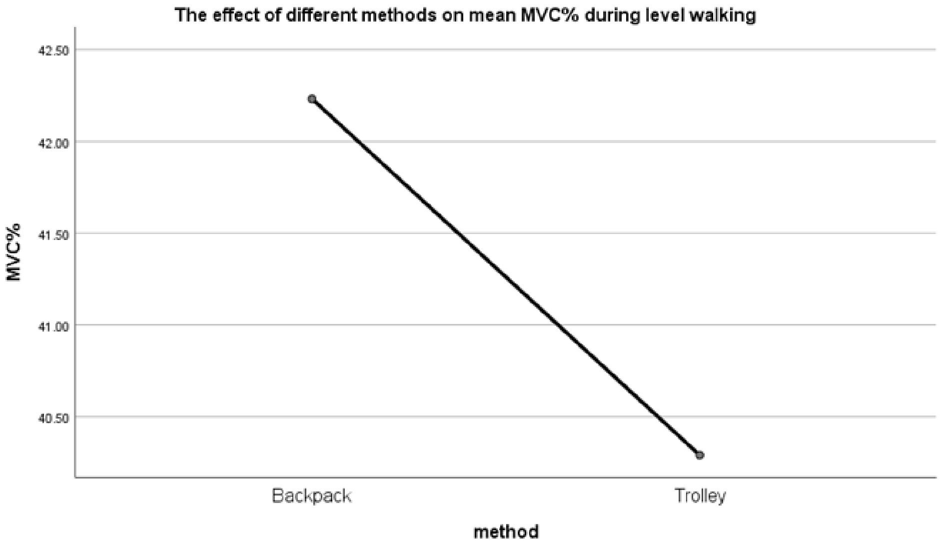


Result of **right tibialis anterior muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**188.017**	**8.568**	**.007**	**.263**	**8.568**	**.802**
weight	2.010	114.744	1.727	.189	.067	3.470	.346
method * weight	2.185	16.669	.649	.540	.026	1.418	.158

a. Computed using alpha = .05

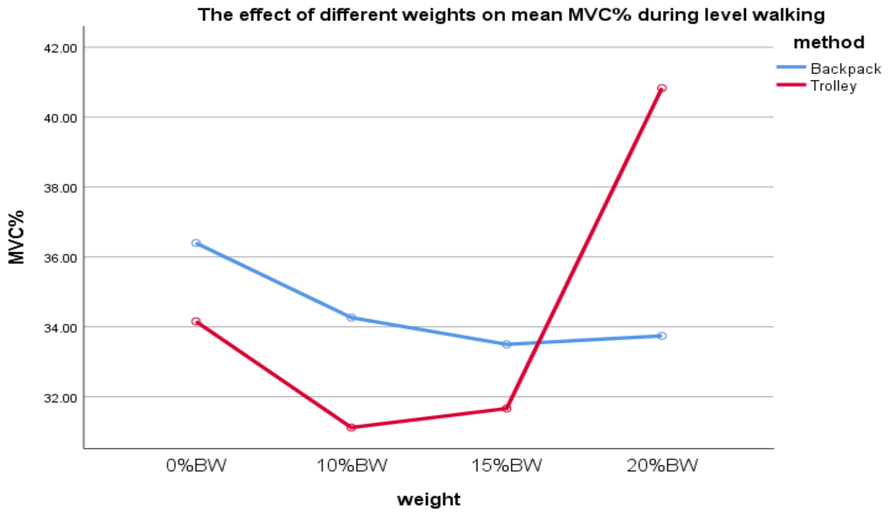




Result of **left gastrocnemius muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	.059	.000	.989	.000	.000	.050
weight	1.142	669.849	.736	.416	.030	.841	.136
method * weight	1.051	815.432	.84	.373	.034	.884	.145

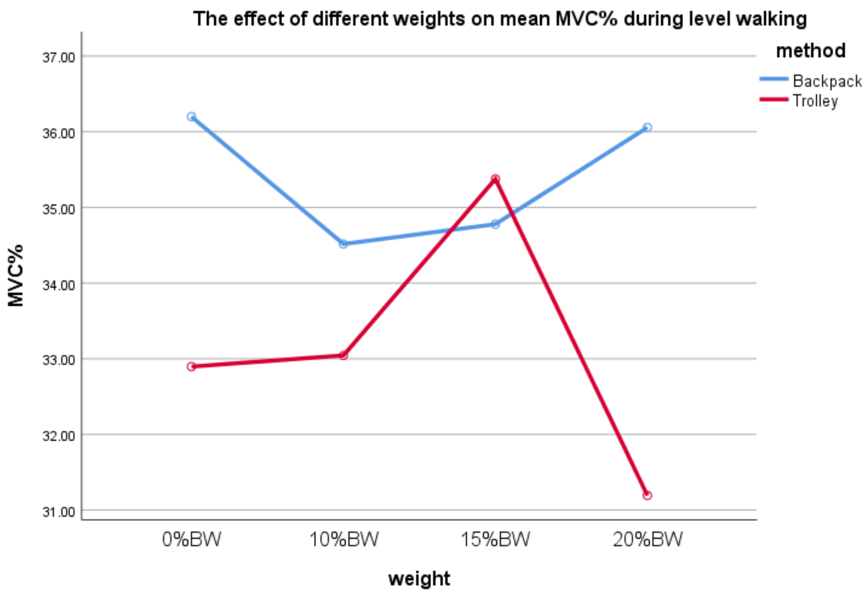
a. Computed using alpha = .05

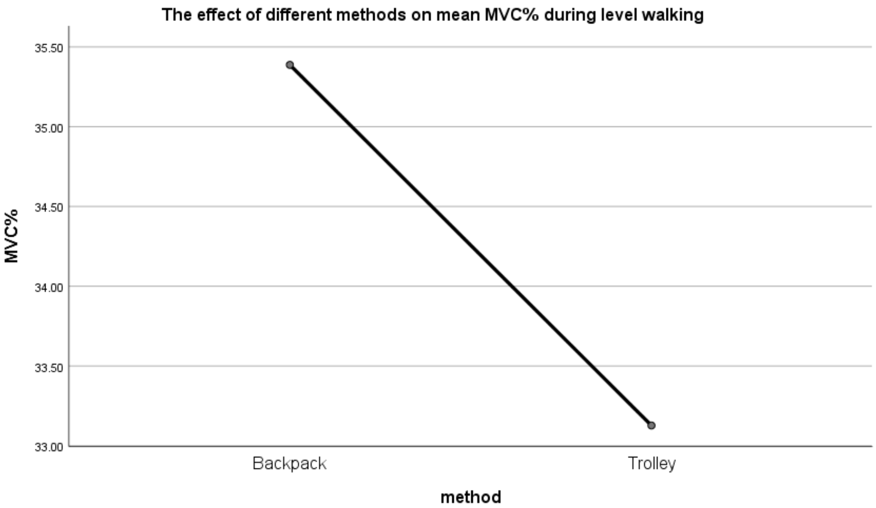


Result of **right gastrocnemius muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**255.514**	**5.487**	**.028**	**.186**	**5.487**	**.613**
weight	1.643	42.131	.540	.553	.022	.887	.126
method * weight	1.632	127.468	2.261	.126	.086	3.691	.391

a. Computed using alpha = .05

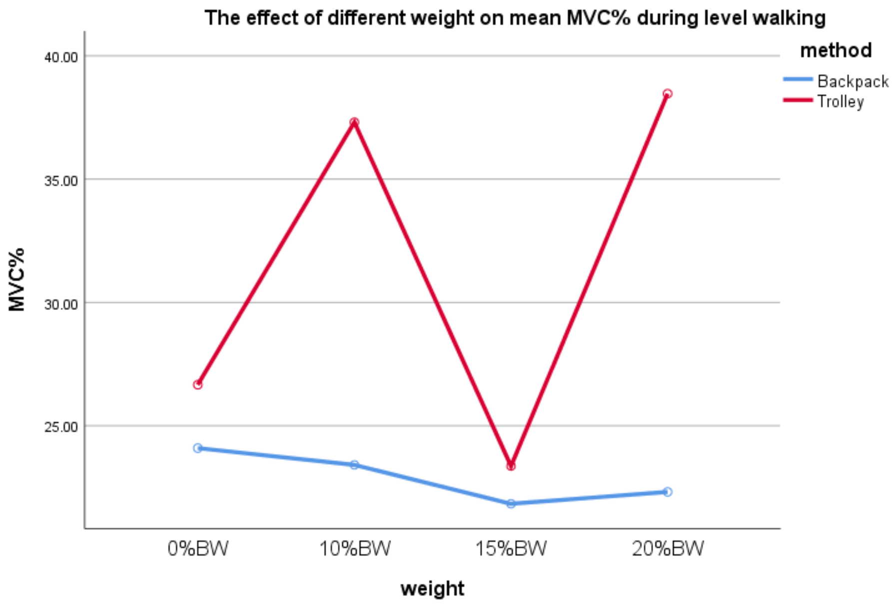




Result of **left semitendinosus muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	3644.350	3.160	.088	.116	3.160	.400
weight	1.769	1262.099	.519	.577	.021	.917	.125
method * weight	1.801	1188.991	.594	.539	.024	1.071	.138

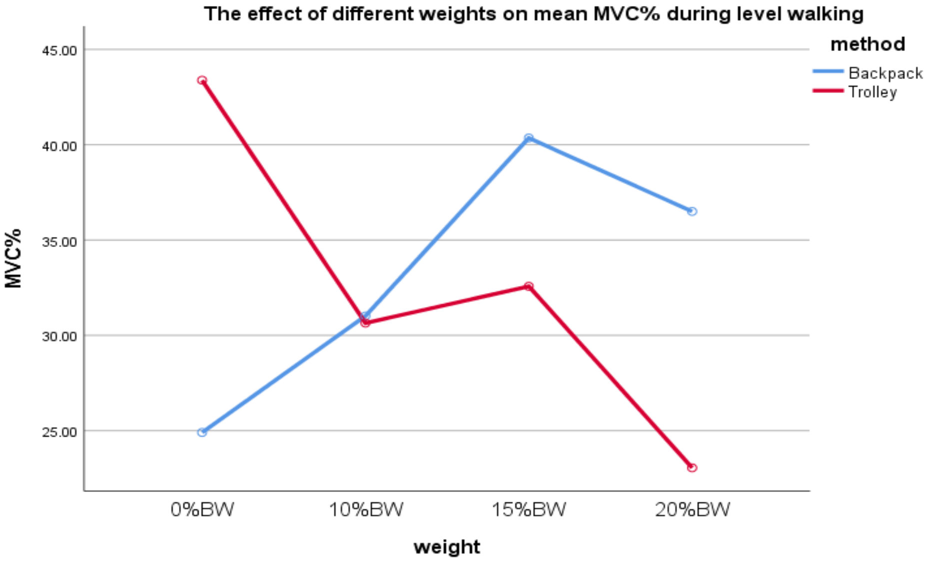
a. Computed using alpha = .05



Result of **right semitendinosus muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	30.522	.077	.783	.003	.077	.058
weight	3	471.015	.590	.623	.024	1.771.	.167
method * weight	1.416	5124.718	2.562	.107	.096	3.629	.404

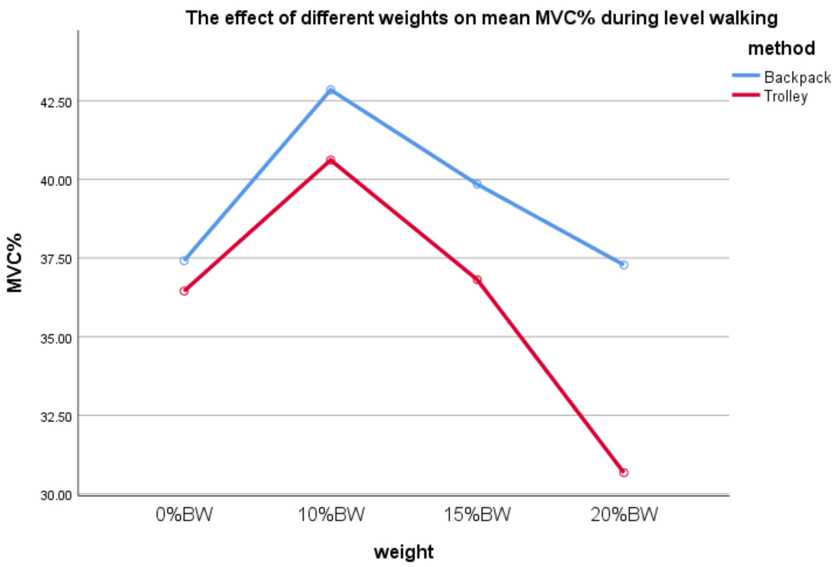
a. Computed using alpha = .05

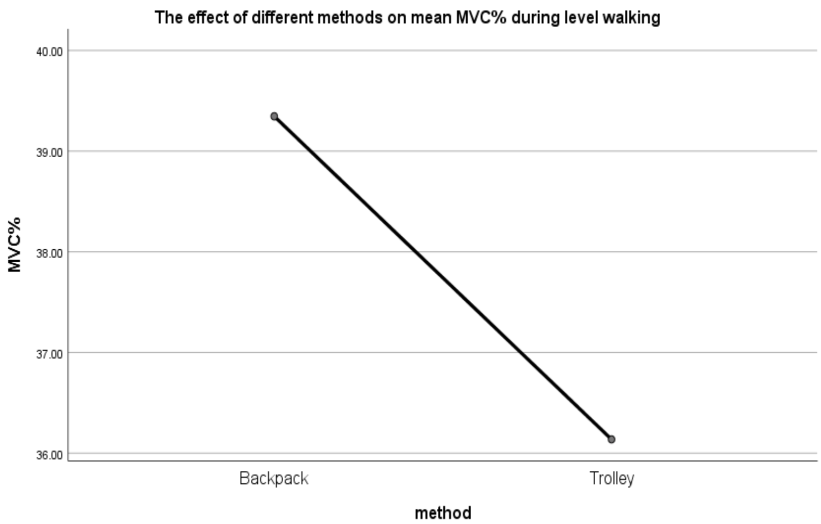


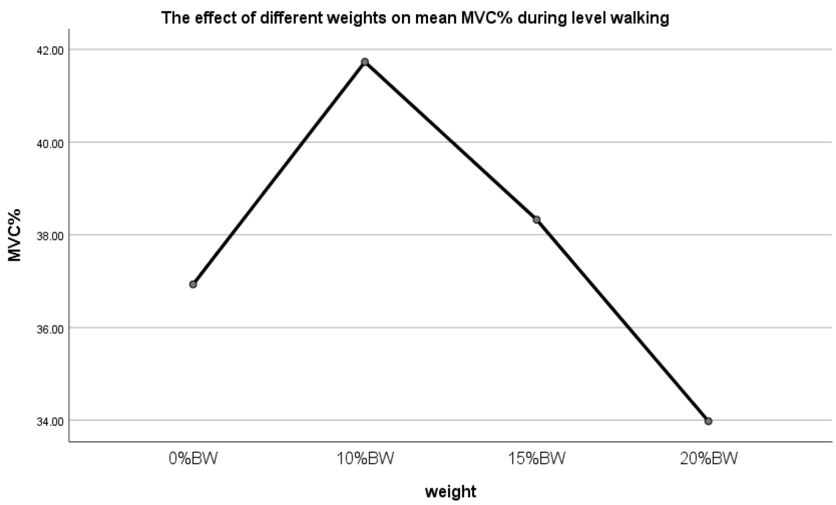
Result of **left rectus femoris muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**515.010**	**5.619**	**.026**	**.190**	**5.619**	**.624**
weight	**1.881**	**825.742**	**5.121**	**.011**	**.176**	**9.633**	**.780**
method * weight	1.742	125.866	1.156	.319	.046	2.014	.227

a. Computed using alpha = .05


The effect of different weights on mean MVC% during level walking
method
Backpack
Trolley
42.50
40.00
37.50
35.00
32.50
30.00
MVC%
0%BW
10%BW
15%BW
20%BW
weight

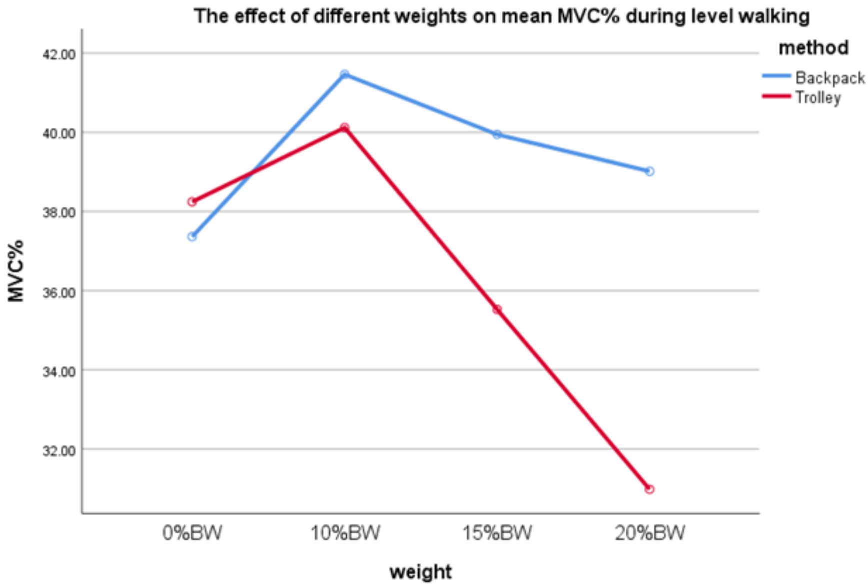

The effect of different methods on mean MVC% during level walking
40.00
39.00
38.00
37.00
36.00
MVC%
Backpack
Trolley
method

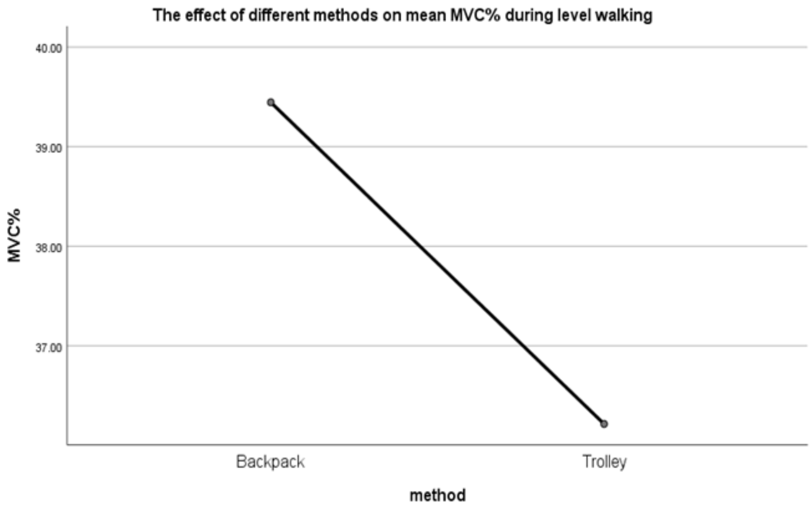

The effect of different weights on mean MVC% during level walking
42.00
40.00
38.00
36.00
34.00
MVC%
0%BW
10%BW
15%BW
20%BW
weight

Result of **right rectus femoris muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**521.923**	**8.922**	**.006**	**.271**	**8.922**	**.817**
weight	1.885	445.557	2.368	.108	.090	4.464	.441
method * weight	1.718	326.996	2.556	.097	.096	4.391	.448

a. Computed using alpha = .05

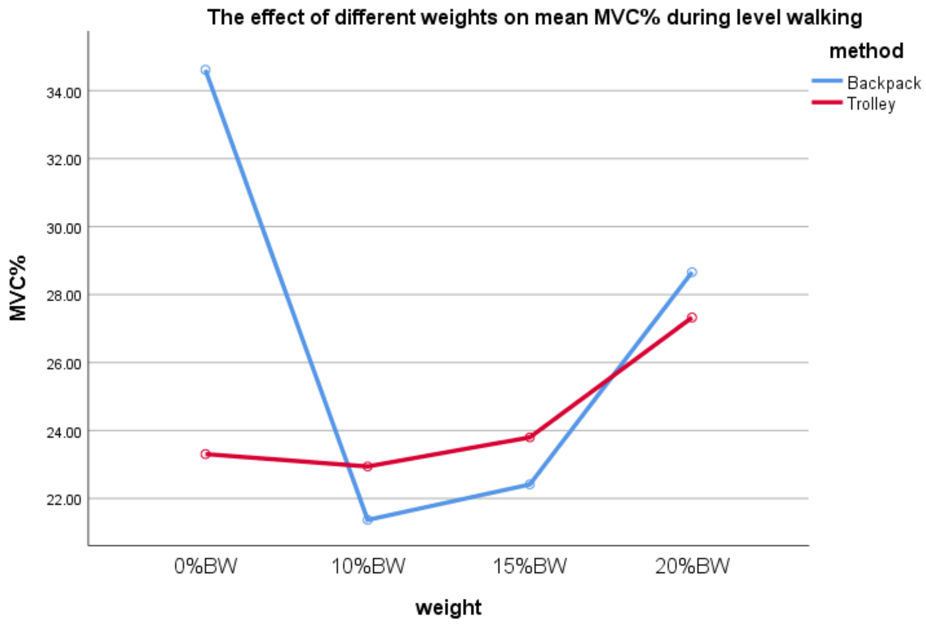


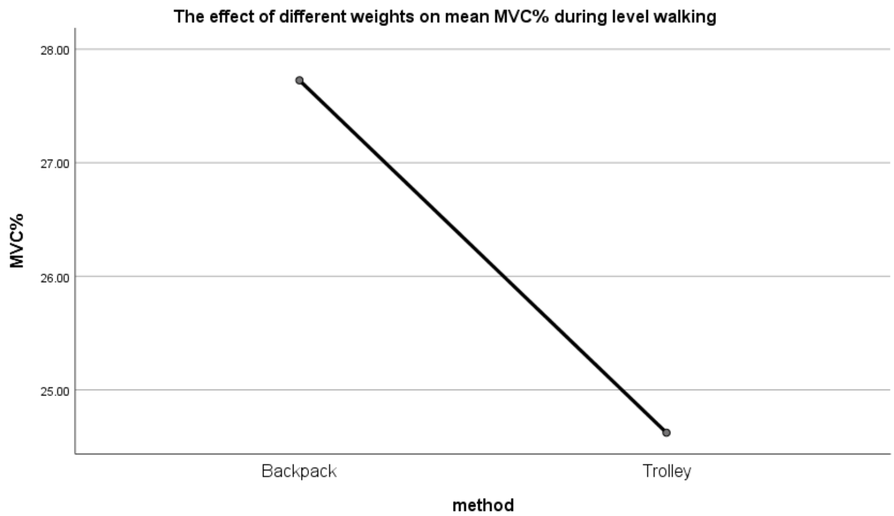


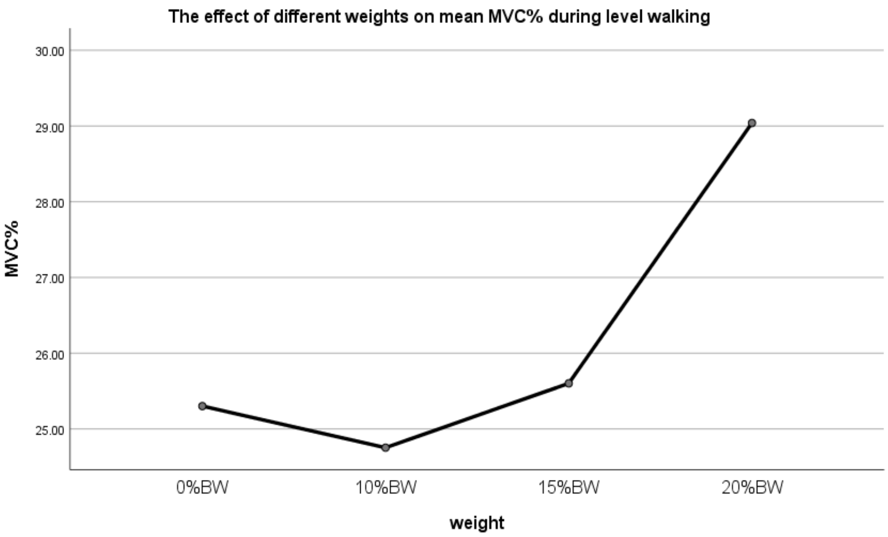
Result of **left lumbar erector spinae muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	293.097	.573	.457	.023	.573	.112
weight	1.224	1432.697	.898	.371	.036	1.100	.160
method * weight	1.138	1214.013	1.003	.336	.040	1.141	.169

a. Computed using alpha = .05


The effect of different weights on mean MVC% during level walking
method
Backpack
Trolley
MVC%
34.00
32.00
30.00
28.00
26.00
24.00
22.00
0%BW
10%BW
15%BW
20%BW
weight

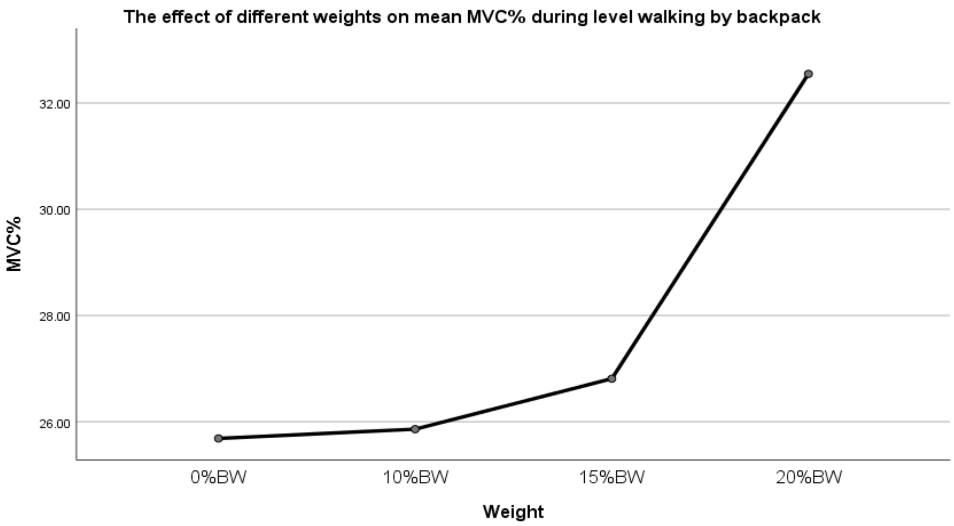

The effect of different weights on mean MVC% during level walking
MVC%
28.00
27.00
26.00
25.00
Backpack
Trolley
method



Result of **right lumbar erector spinae muscle** (mean MVC%) during **level walking** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**2.121**	**374.215**	**6.447**	**.003**	**.212**	**13.675**	**.900**

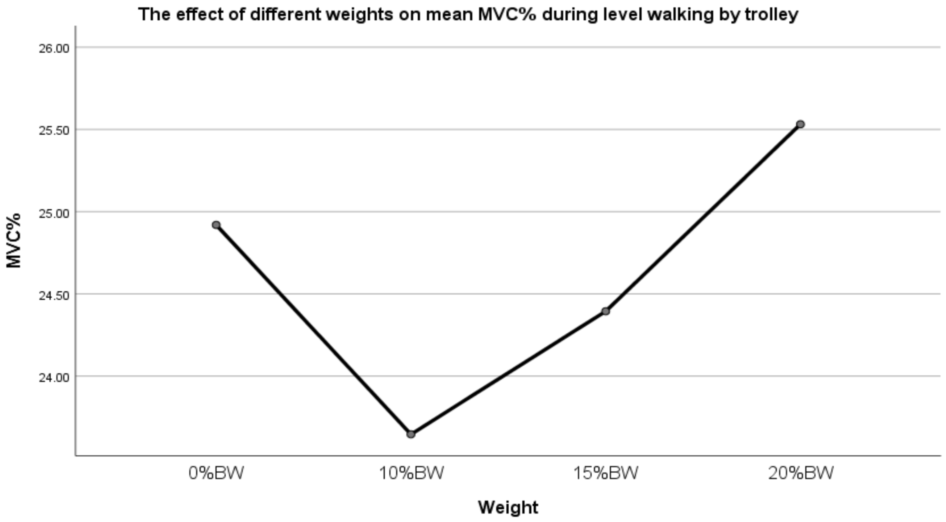
a. Computed using alpha = .05



Result of **right lumbar erector spinae muscle** (mean MVC%) during **level walking** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	2.037	23.568	.527	.597	.021	1.073	.133

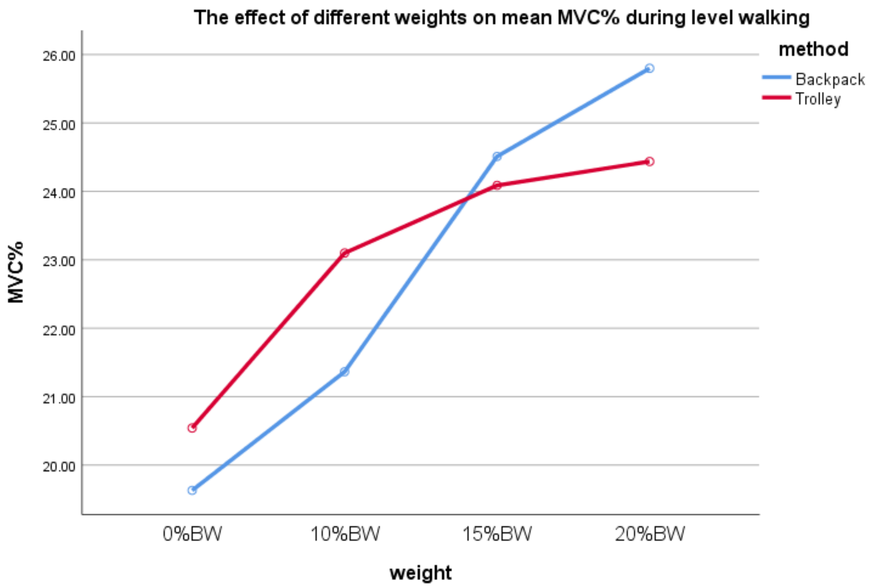
a. Computed using alpha = .05

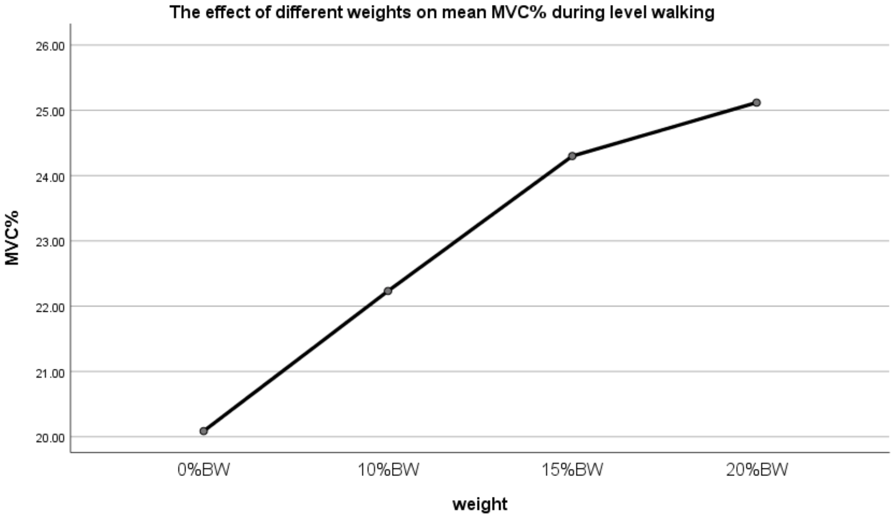


Result of **left abdominal muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	2.320	.088	.769	.004	.088	.059
weight	**1.652**	**461.169**	**9.302**	**.001**	**.279**	**15.368**	**.945**
method * weight	**2.120**	**33.544**	**3.494**	**.035**	**.127**	**7.407**	**.644**

a. Computed using alpha = .05

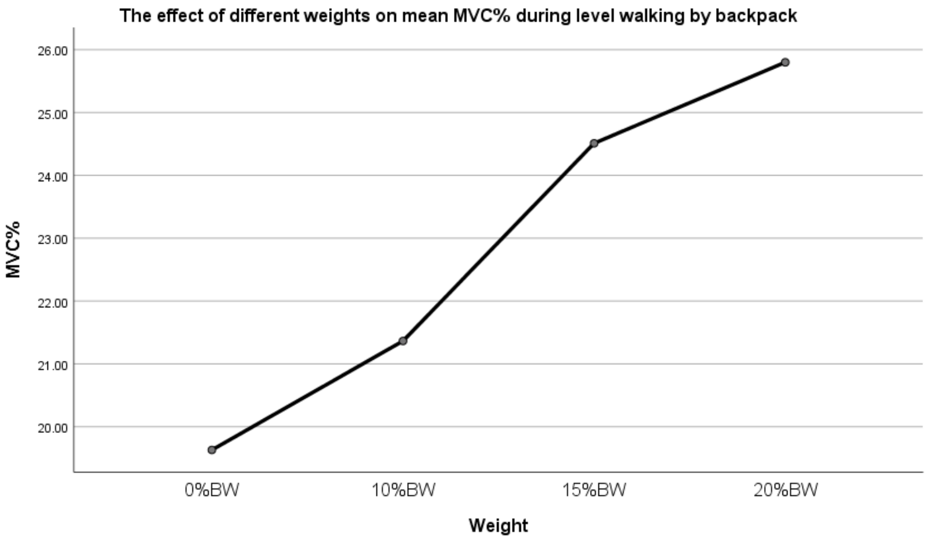




Result of **left abdominal muscle** (mean MVC%) during **level walking** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.884**	**318.833**	**12.252**	**.000**	**.338**	**23.082**	**.991**

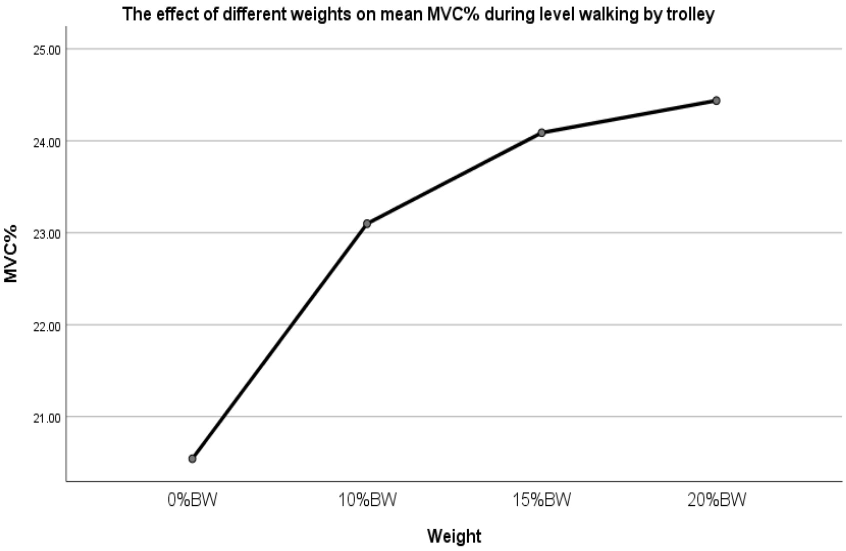
a. Computed using alpha = .05



Result of **left abdominal muscle** (mean MVC%) during **level walking** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.456**	**159.611**	**4.365**	**.031**	**.154**	**6.353**	**.627**

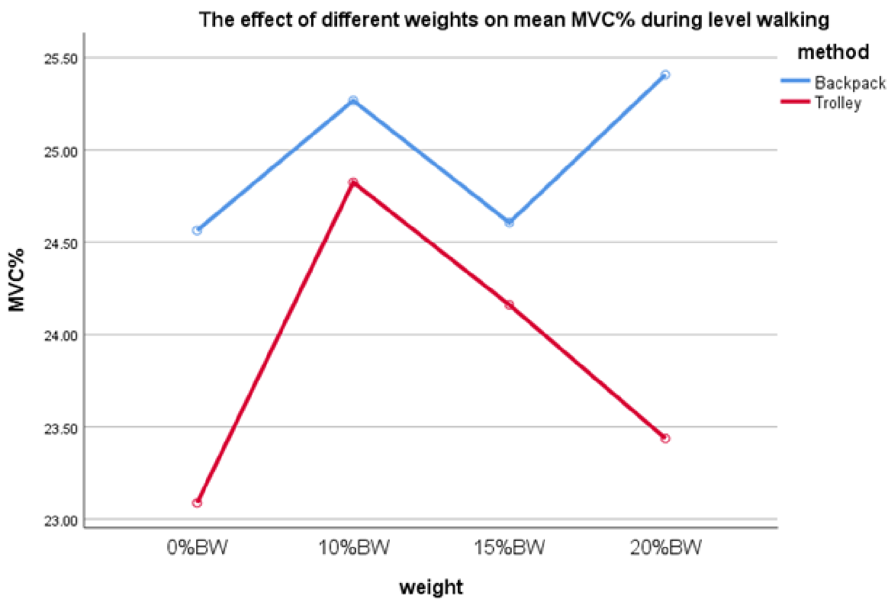
a. Computed using alpha = .05

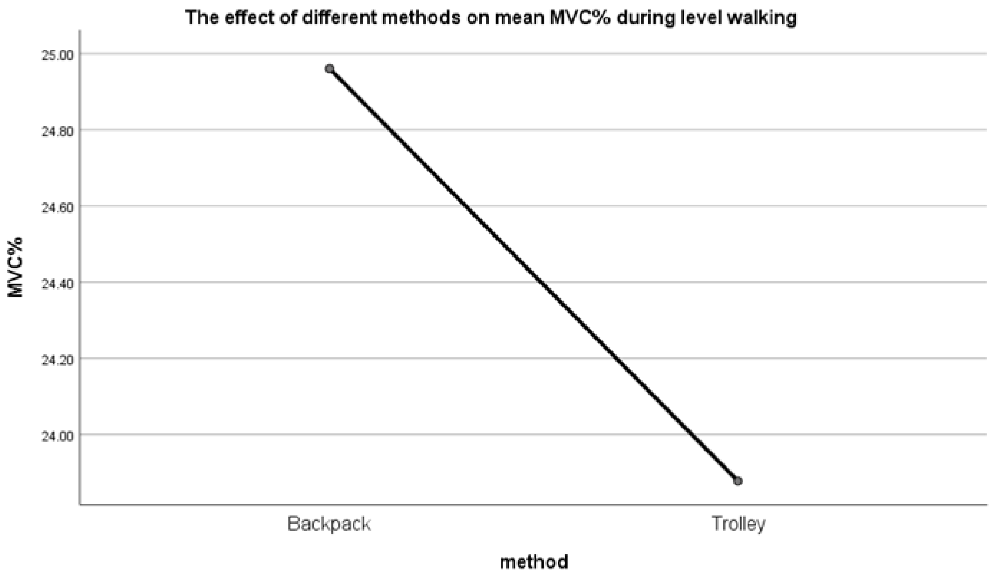


Result of **right abdominal muscle** (mean MVC%) during **level walking**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**58.640**	**4.607**	**.042**	**.161**	**4.607**	**.540**
weight	1.041	35.782	.081	.788	.003	.085	.059
method * weight	1.495	14.678	.945	.374	.038	1.412	.180

a. Computed using alpha = .05

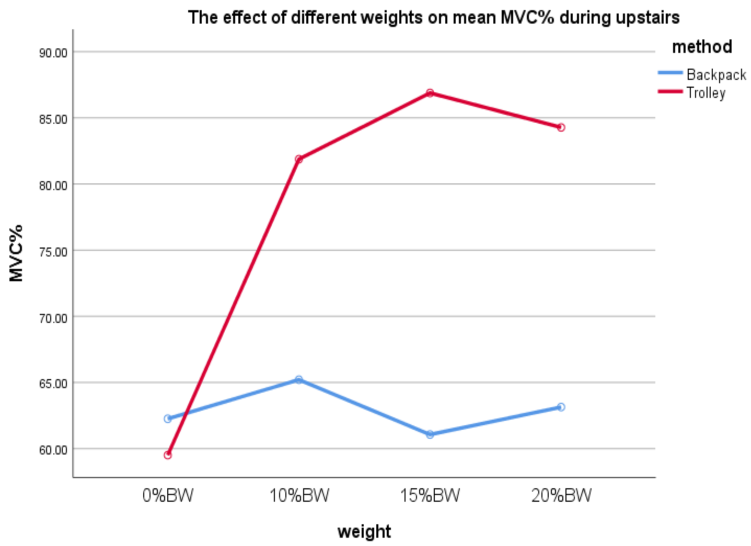


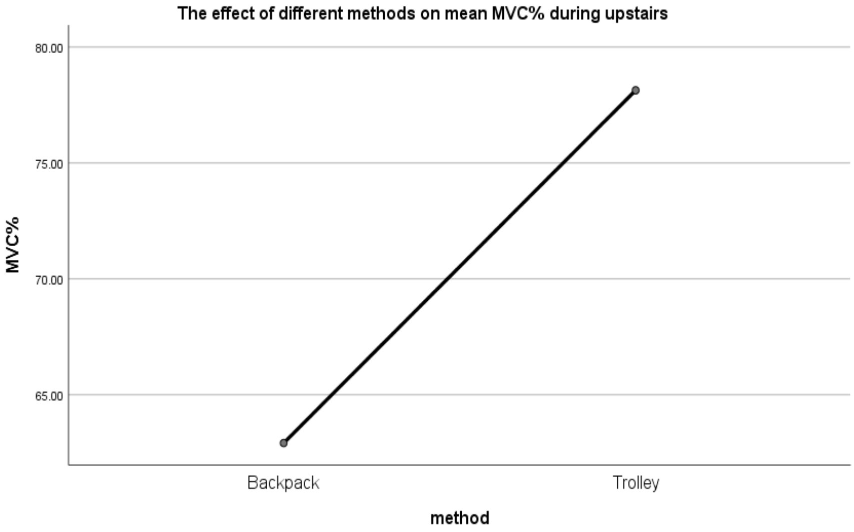


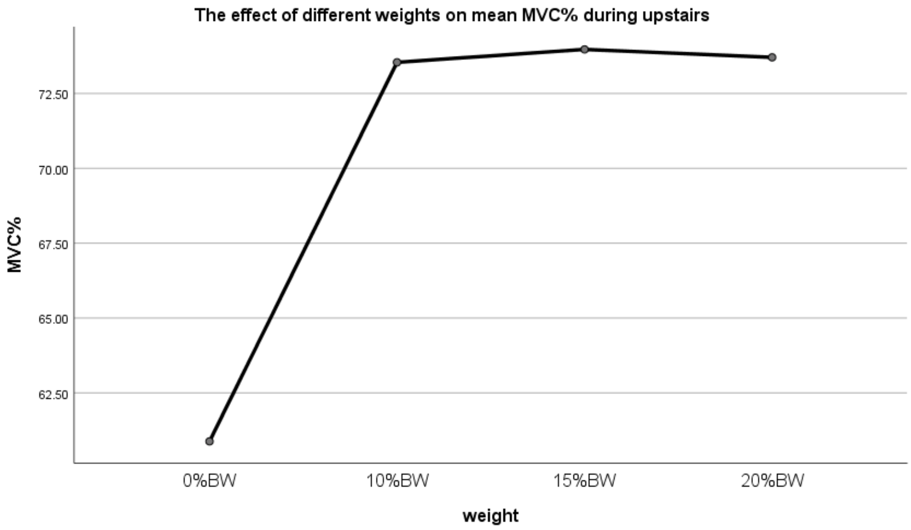
Result of **left tibialis anterior muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**11578.136**	**12.776**	**.002**	**.347**	**12.776**	**.929**
weight	**1.555**	**3990.082**	**5.884**	**.010**	**.197**	**9.152**	**.781**
method * weight	**1.198**	**4928.577**	**6.183**	**.001**	**.205**	**7.405**	**.721**

a. Computed using alpha = .05



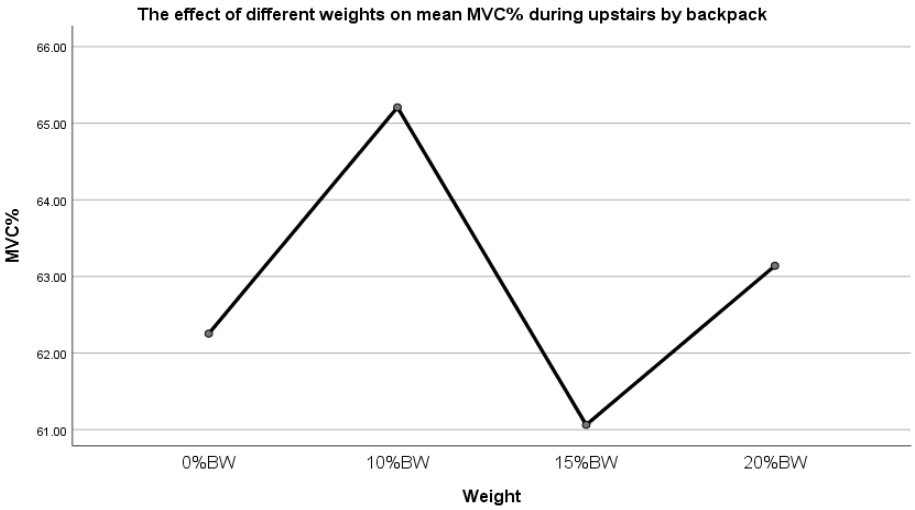




Result of **left tibialis anterior muscle** (mean MVC%) during **upstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	2.197	104.367	1.369	.264	.054	3.008	.295

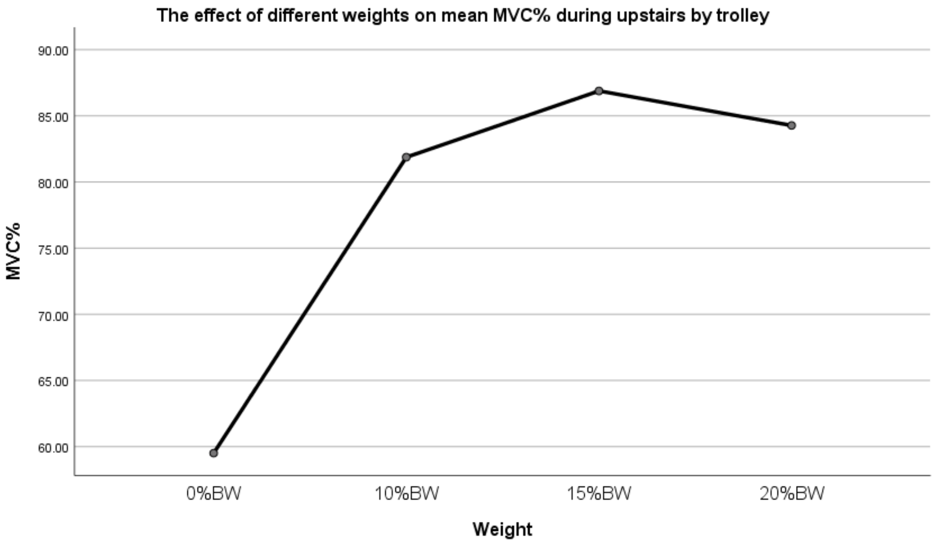
a. Computed using alpha = .05



Result of **left tibialis anterior muscle** (mean MVC%) during **upstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.246**	**9530.208**	**6.450**	**.012**	**.212**	**8.040**	**.752**

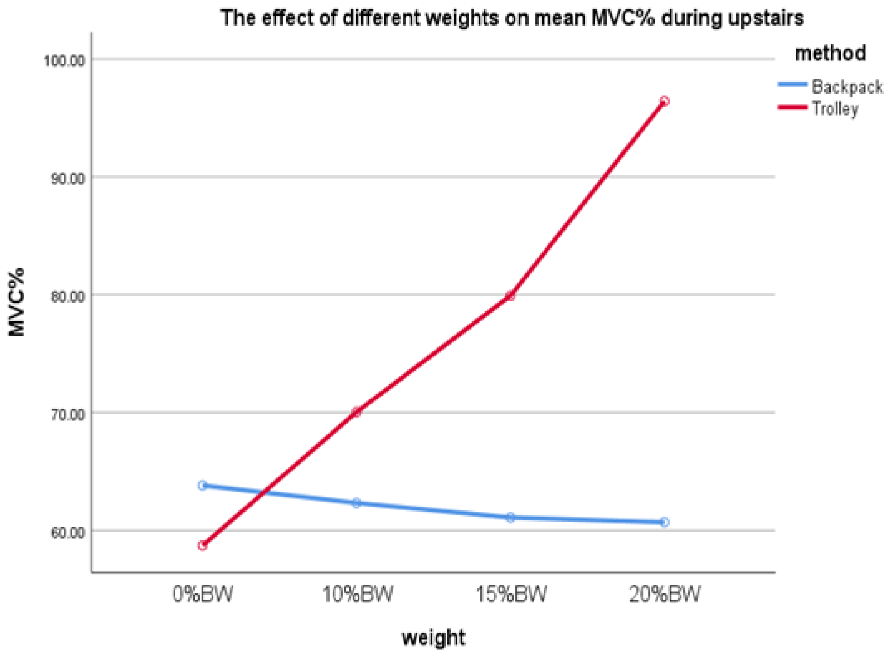
a. Computed using alpha = .05

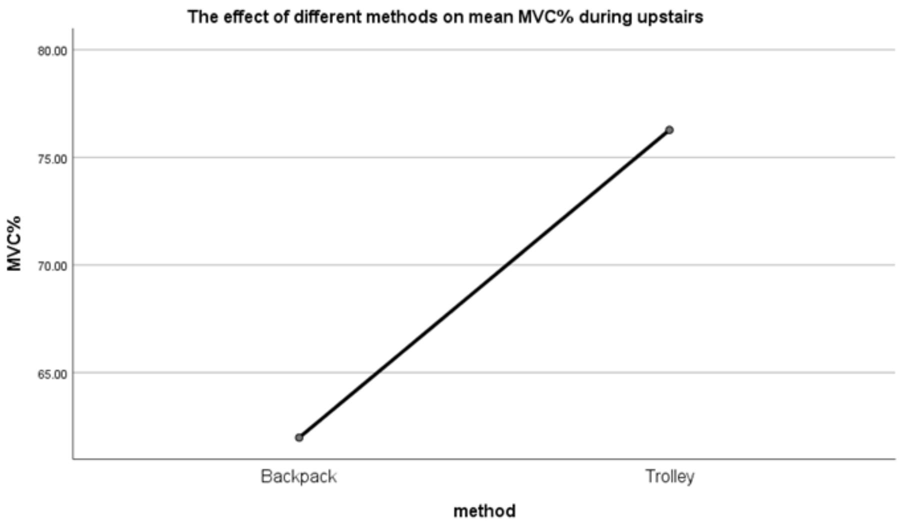


Result of **right tibialis anterior muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**10223.003**	**8.852**	**.007**	**.269**	**8.852**	**.814**
weight	1.424	5663.317	2.447	.116	.093	3.485	.389
method * weight	1.310	8584.901	3.460	.062	.126	4.533	.497

a. Computed using alpha = .05

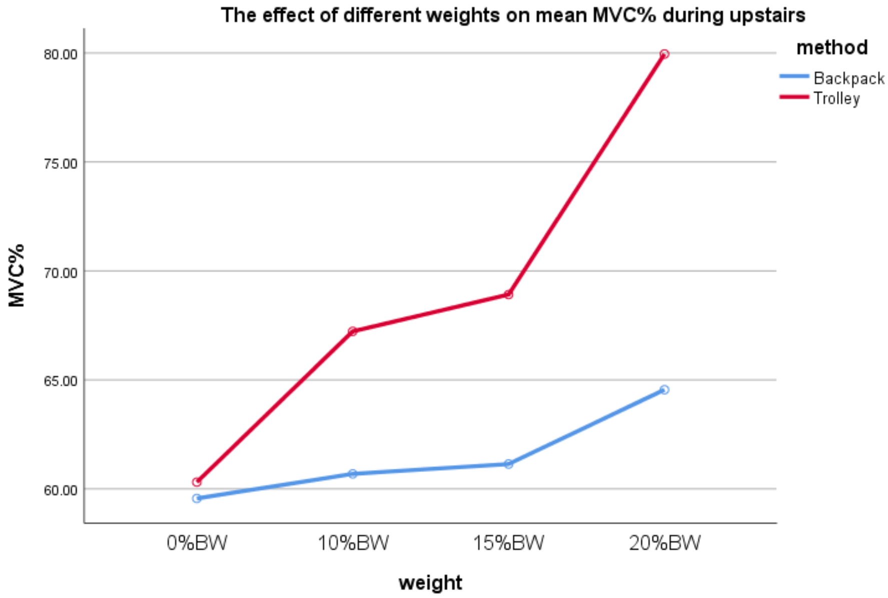


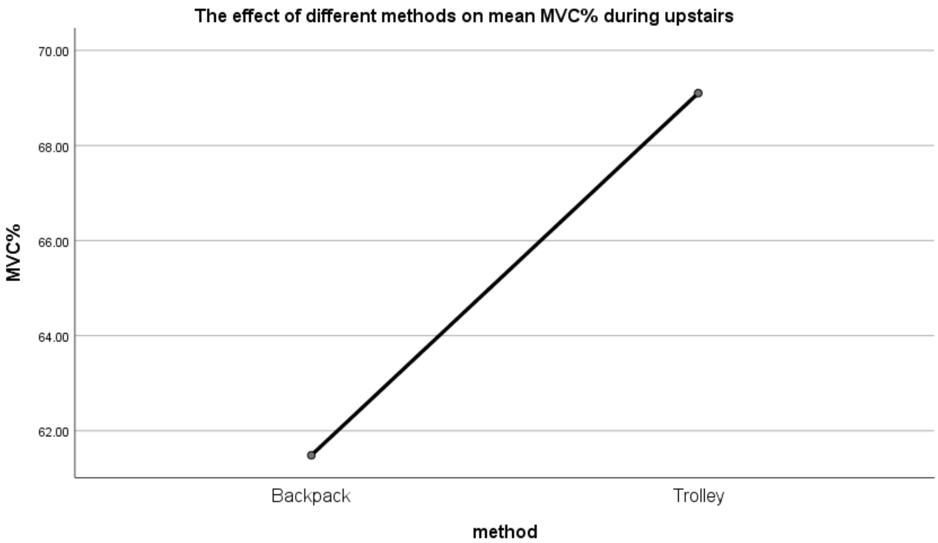


Result of **left gastrocnemius muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**2901.079**	**7.104**	**.014**	**.228**	**7.104**	**.725**
weight	1.679	2352.079	2.453	.107	.093	4.119	.427
method * weight	1.393	978.137	1.534	.230	.060	2.137	.258

a. Computed using alpha = .05

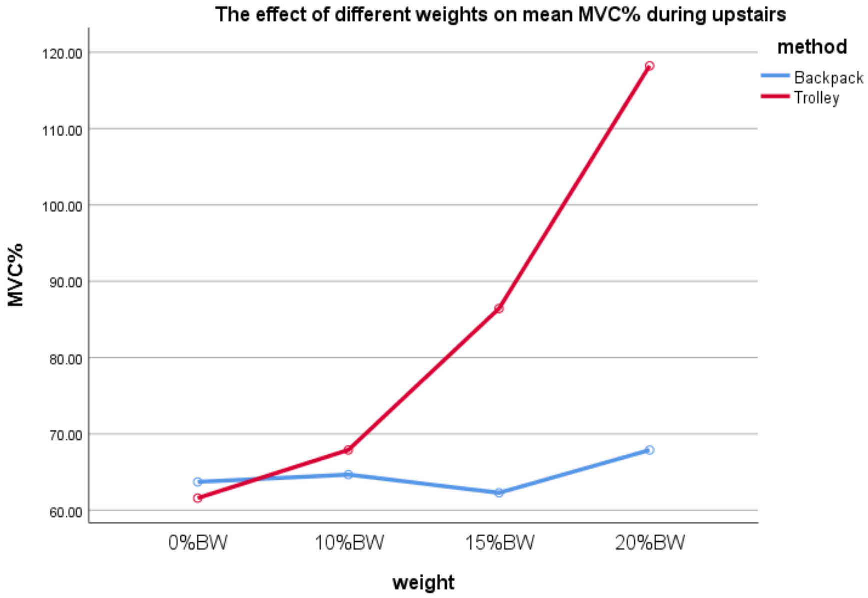




Result of **right gastrocnemius muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	17864.130	2.3333	.140	.089	2.333	.311
weight	1.040	26525.556	2.235	.147	.085	2.325	.306
method * weight	1.022	20853.798	1.661	.210	.065	1.697	.238

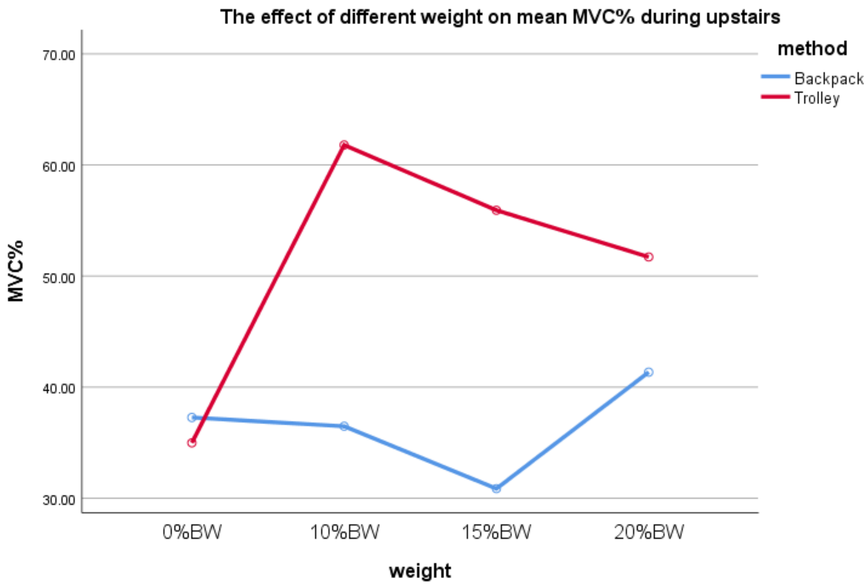
a. Computed using alpha = .05

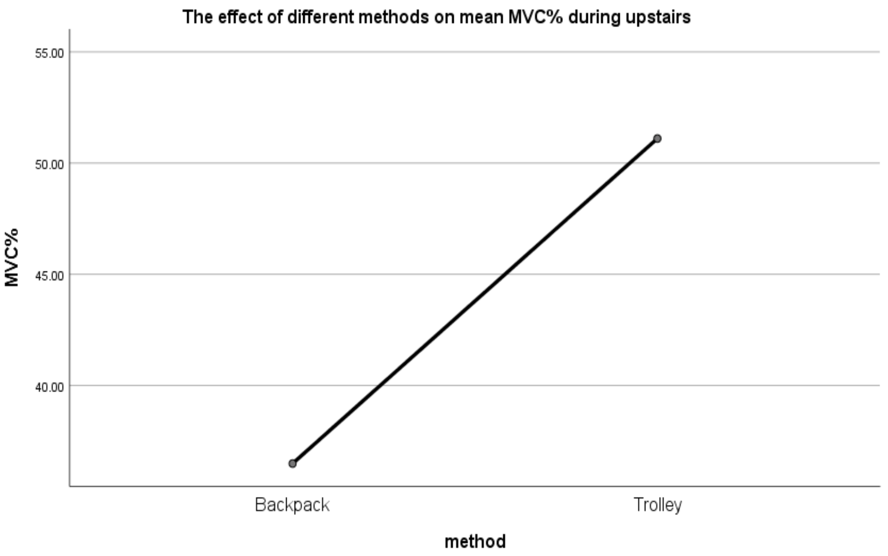


Result of **left semitendinosus muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**10682.067**	**6.484**	**.018**	**.213**	**6.484**	**.686**
weight	1.589	2989.215	.992	.363	.040	1.576	.192
method * weight	1.692	3895.065	1.627	.211	.063	2.753	.299

a. Computed using alpha = .05

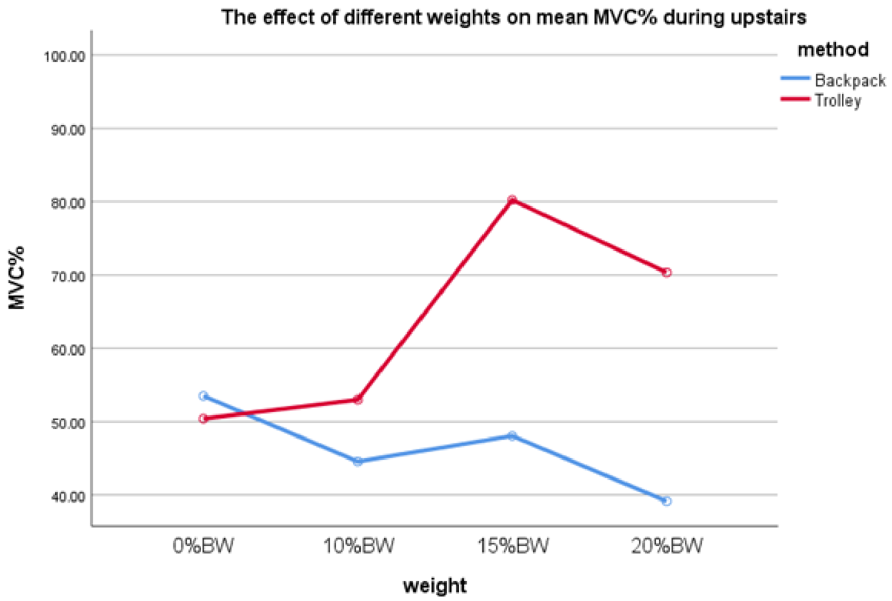


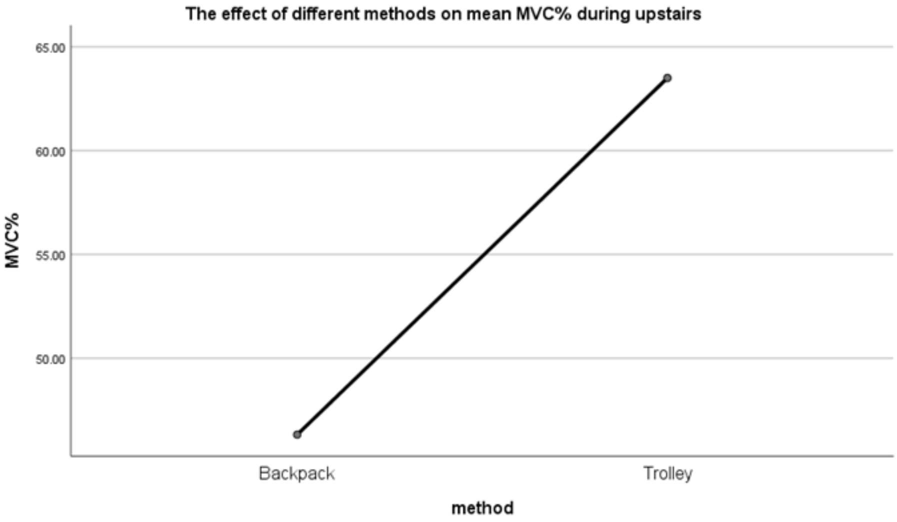


Result of **right semitendinosus muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**14755.301**	**8.774**	**.007**	**.268**	**8.774**	**.811**
weight	1.827	3605.478	1.637	.208	.064	2.991	.313
method * weight	2.016	5639.880	2.375	.103	.090	4.789	.459

a. Computed using alpha = .05

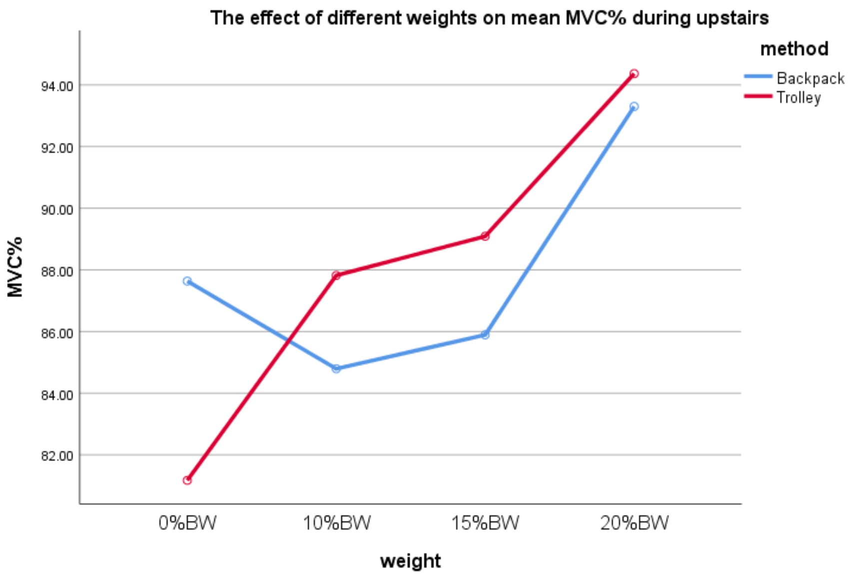


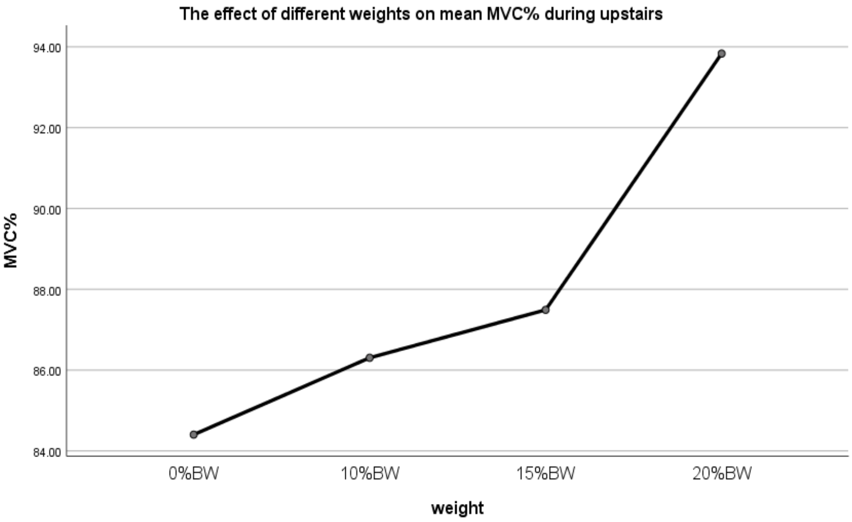


Result of **left rectus femoris muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	2.139	.005	.943	.000	.005	.051
weight	**1.900**	**1317.869**	**3.635**	**.036**	**.132**	**6.908**	**.627**
method * weight	3	258.842	1.239	.302	.049	3.718	.319

a. Computed using alpha = .05

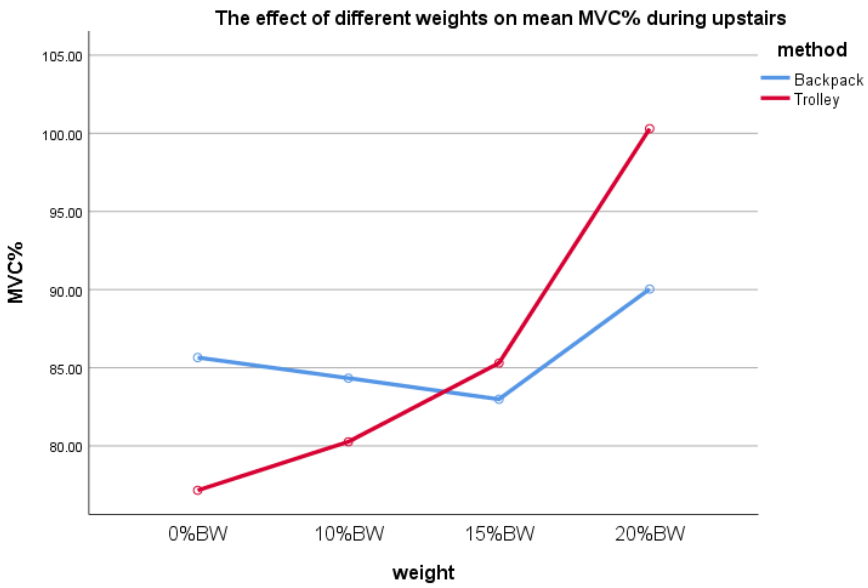




Result of **right rectus femoris muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	.001	.000	.999	.000	.000	.050
weight	1.286	4743.514	2.380	.127	.090	3.061	.360
method * weight	1.581	1577.743	.874	.403	.035	1.381	.174

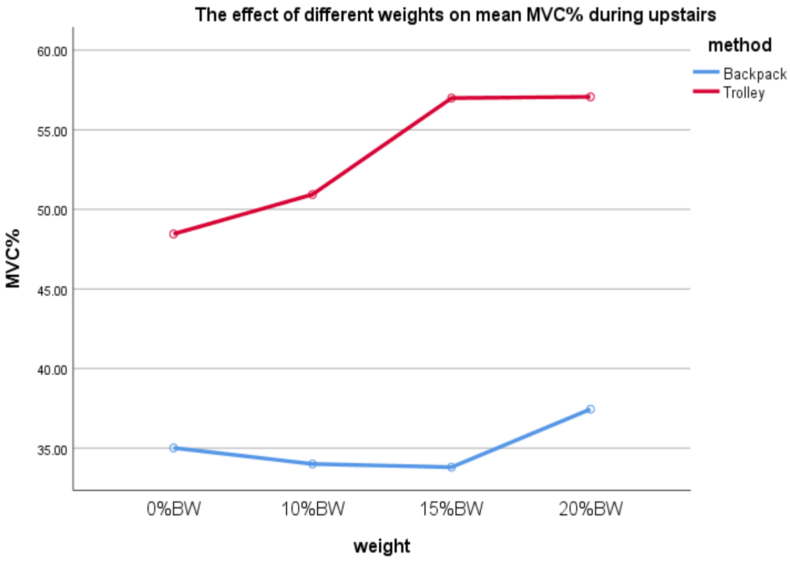
a. Computed using alpha = .05

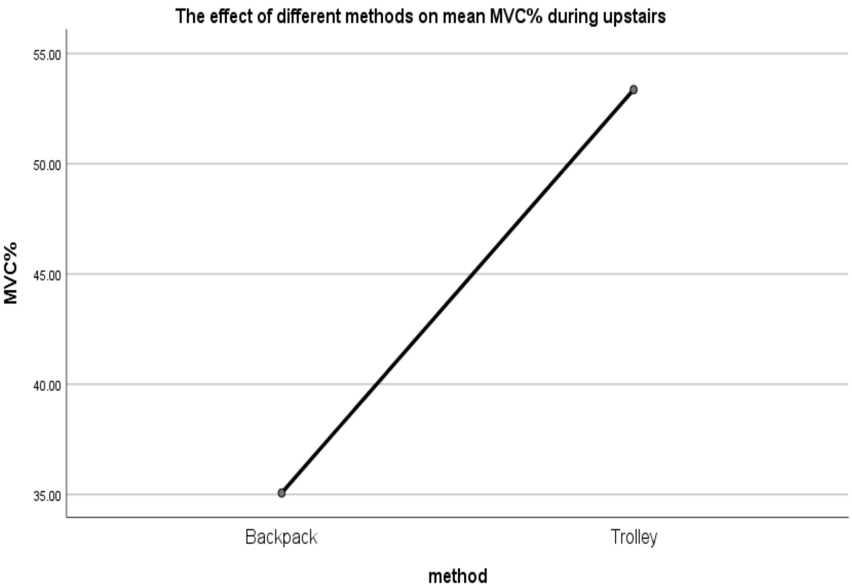


Result of **left lumbar erector spinae muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**16737.501**	**69.558**	**.000**	**.746**	**69.558**	**1.000**
weight	1.095	906.883	.808	.388	.033	.885	.143
method * weight	1.160	551.599	.651	.449	.026	.755	.127

a. Computed using alpha = .05

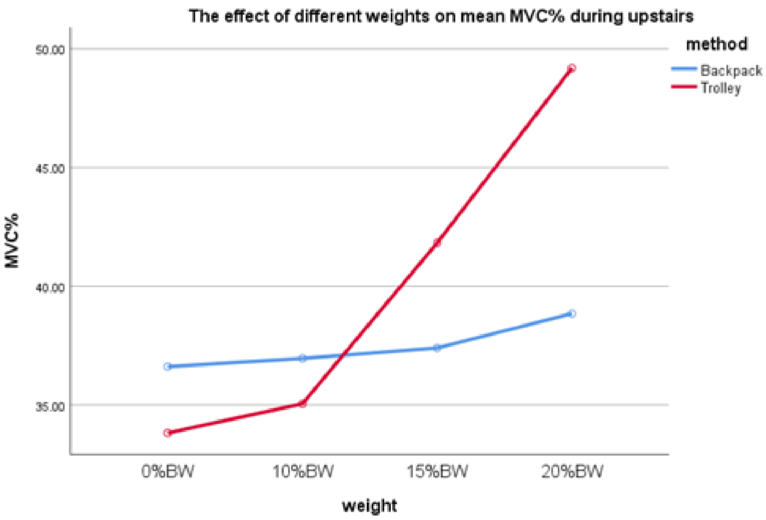


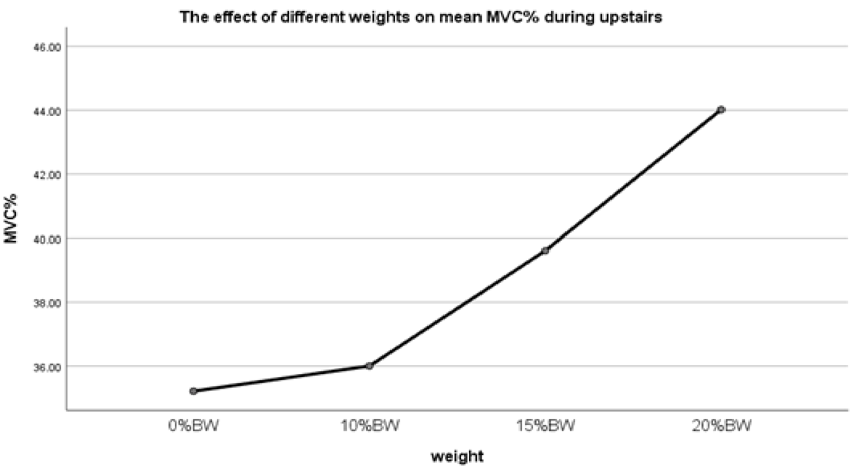


Result of **right lumbar erector spinae muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	316.607	3.595	.070	.130	3.595	.444
weight	**1.818**	**1334.430**	**15.571**	**.000**	**.393**	**28.307**	**.998**
method * weight	**2.102**	**670.586**	**15.085**	**.000**	**.386**	**31.705**	**.999**

a. Computed using alpha = .05

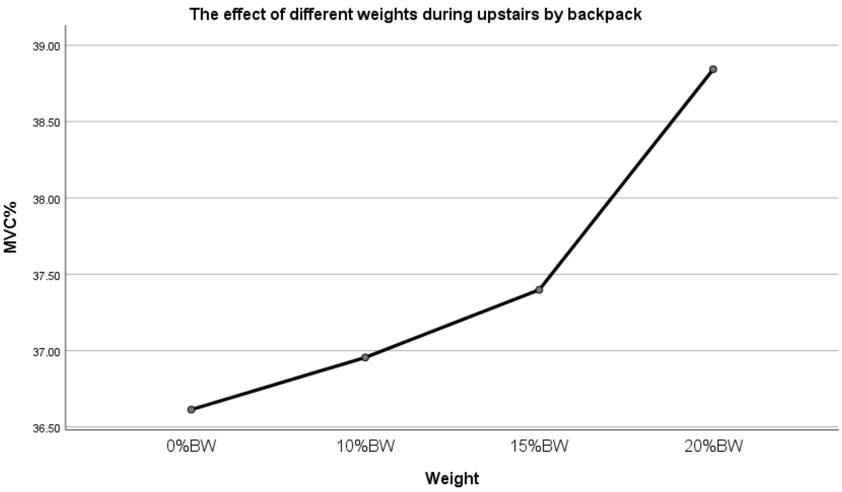




Result of **right lumbar erector spinae muscle** (mean MVC%) during **upstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.915	37.688	1.040	.359	.042	1.992	.217

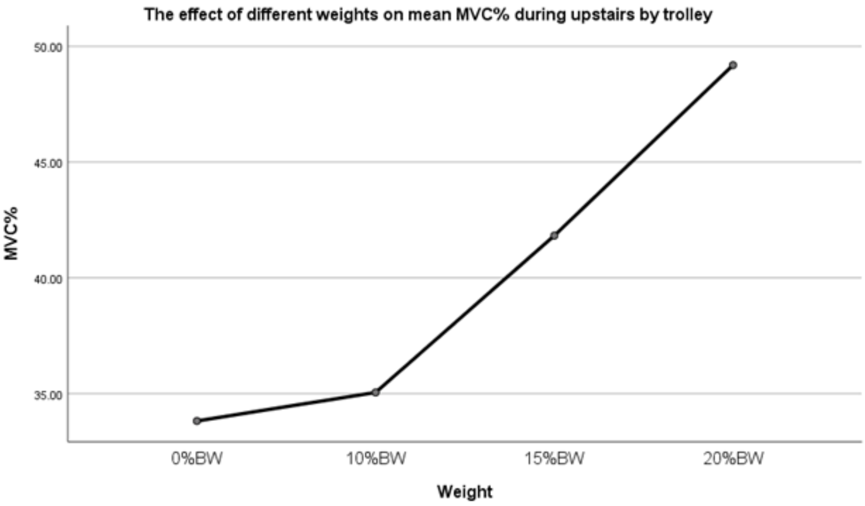
a. Computed using alpha = .05



Result of **right lumbar erector spinae muscle** (mean MVC%) during **upstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.891**	**1989.589**	**20.925**	**.000**	**.466**	**39.577**	**1.000**

a. Computed using alpha = .05



Result of **left abdominal muscle** (mean MVC%) during **upstairs**

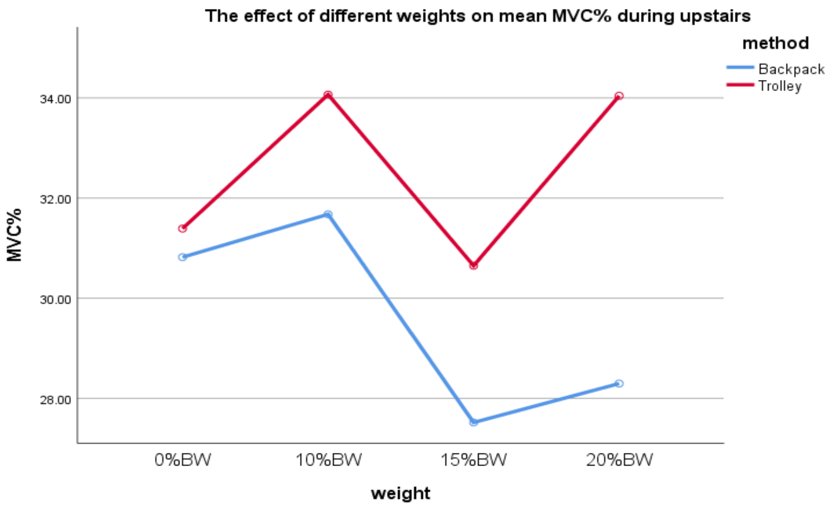
Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	1795.123	3.226	.085	.118	3.226	.407
weight	1.146	2154.507	2.165	.151	.083	2.481	.313
method * weight	1.184	2054.009	2.515	.119	.095	2.977	.361

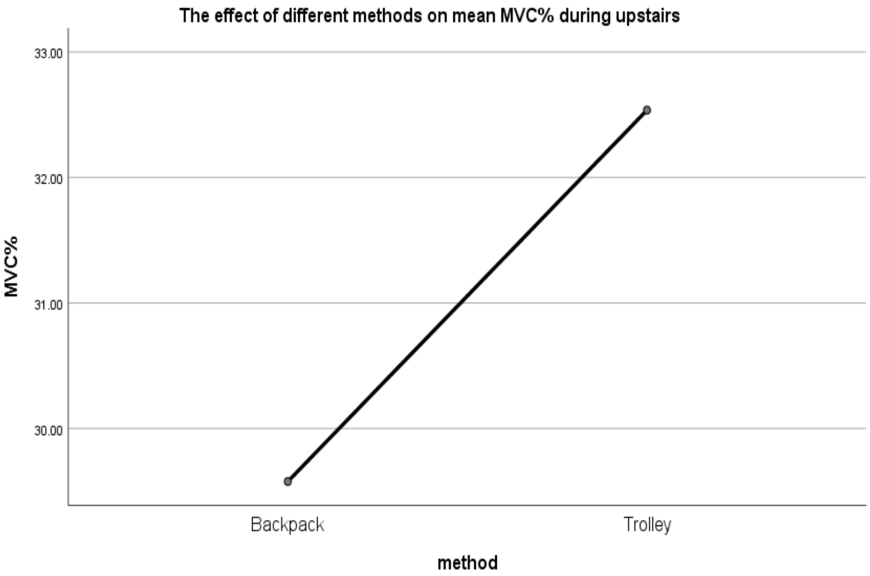
a. Computed using alpha = .05

Result of **right abdominal muscle** (mean MVC%) during **upstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**438.080**	**6.027**	**.022**	**.201**	**6.027**	**.654**
weight	1.014	355.287	.259	.618	.011	.263	.078
method * weight	**1.564**	**110.428**	**3.696**	**.044**	**.133**	**5.783**	**.575**

a. Computed using alpha = .05

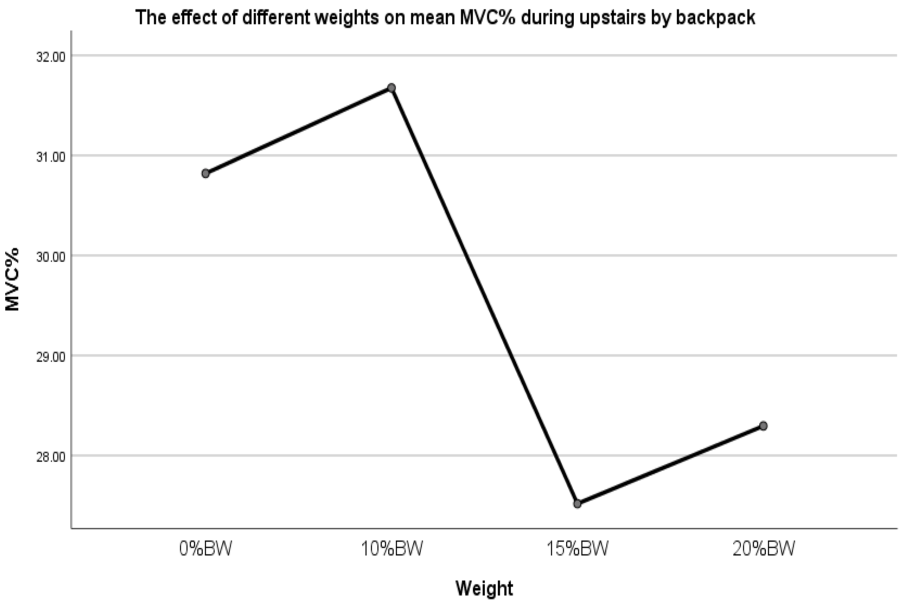




Result of **right abdominal muscle** (mean MVC%) during **upstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.014	291.752	.422	.525	.017	.428	.096

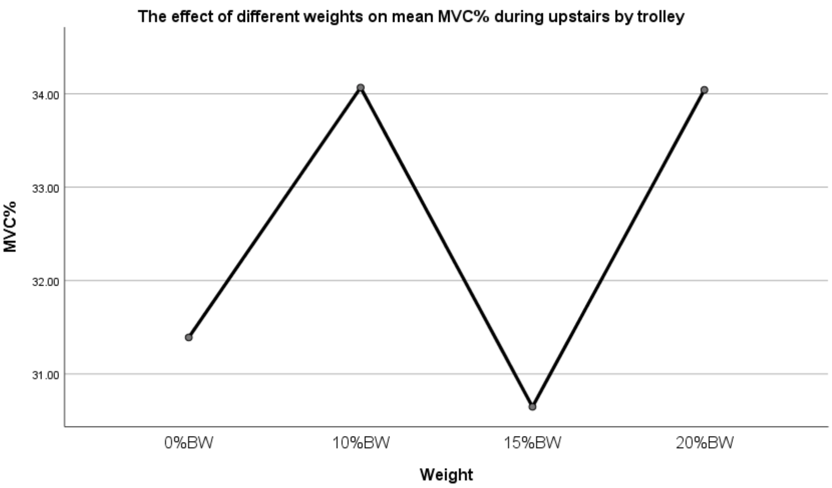
a. Computed using alpha = .05



Result of **right abdominal muscle** (mean MVC%) during **upstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.055	224.671	.323	.587	.013	.341	.086

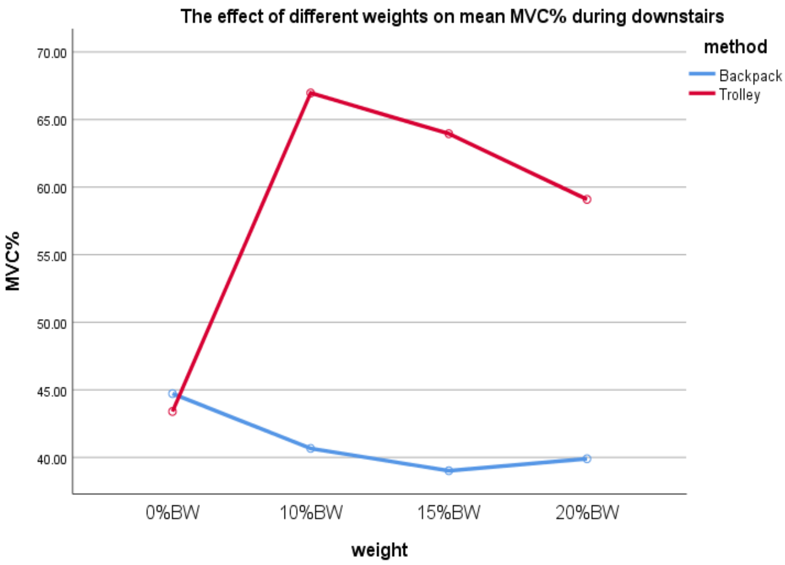
a. Computed using alpha = .05

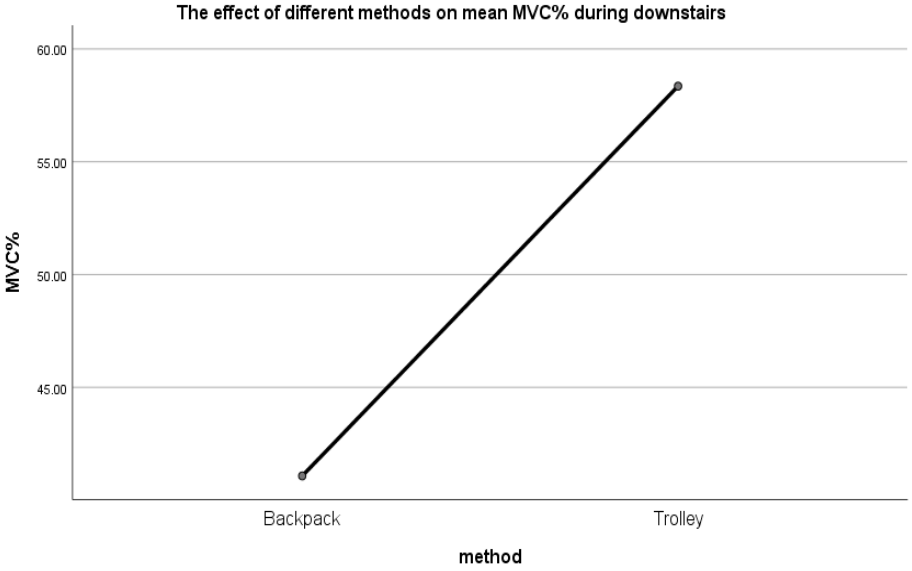


Result of **left tibialis anterior muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**14926.870**	**13.550**	**.001**	**.361**	**13.550**	**.942**
weight	1.537	1691.410	.779	.435	.031	1.197	.158
method * weight	1.465	4179.398	1.882	.175	.073	2.757	.315

a. Computed using alpha = .05

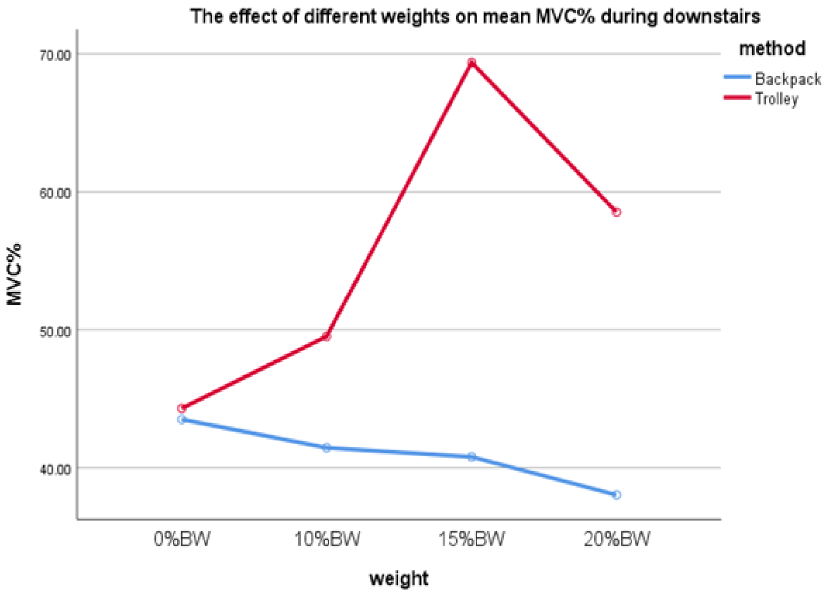


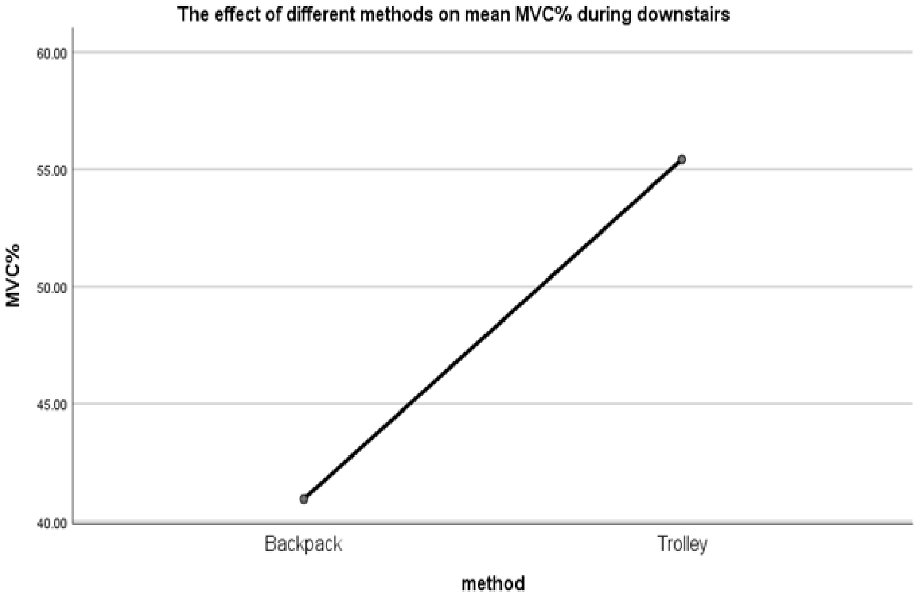


Result of **right tibialis anterior muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**10505.645**	**21.035**	**.000**	**.467**	**21.035**	**.993**
weight	1.447	2529.982	2.797	.090	.104	4.048	.440
method * weight	1.279	4534.852	4.471	.034	.157	5.719	.598

a. Computed using alpha = .05

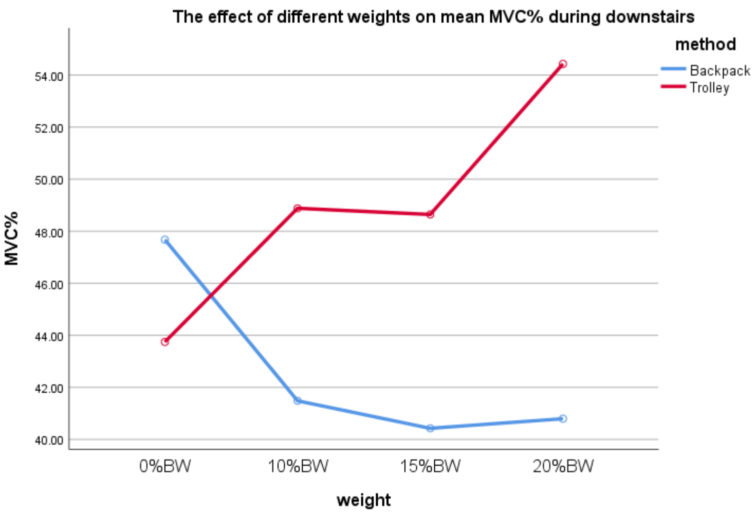


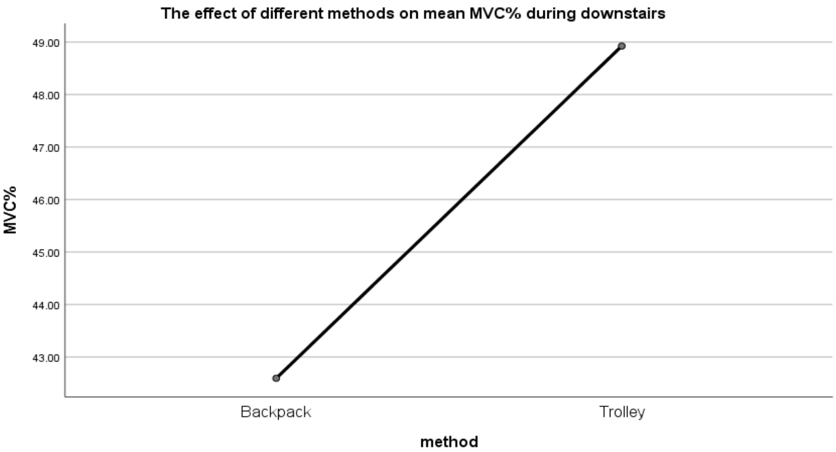


Result of **left gastrocnemius muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**2003.343**	**10.546**	**.003**	**.305**	**10.546**	**.876**
weight	3	87.759	.688	.562	.028	1.653	.171
method * weight	**1.815**	**1124.151**	**7.171**	**.003**	**.230**	**13.015**	**.897**

a. Computed using alpha = .05

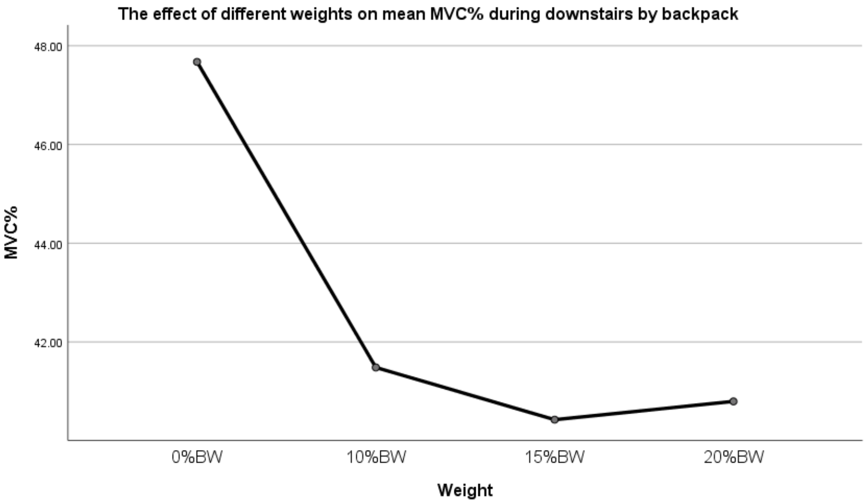




Result of **left gastrocnemius muscle** (mean MVC%) during **downstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.324	660.295	3.751	.051	.135	4.965	.533

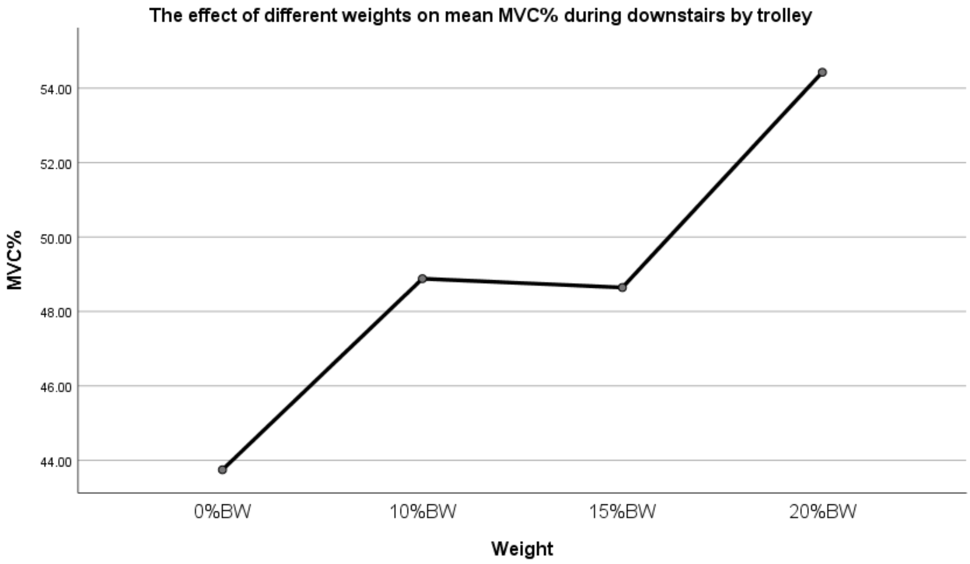
a. Computed using alpha = .05



Result of **left gastrocnemius muscle** (mean MVC%) during **downstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**1.942**	**736.118**	**3.293**	**.047**	**.121**	**6.396**	**.589**

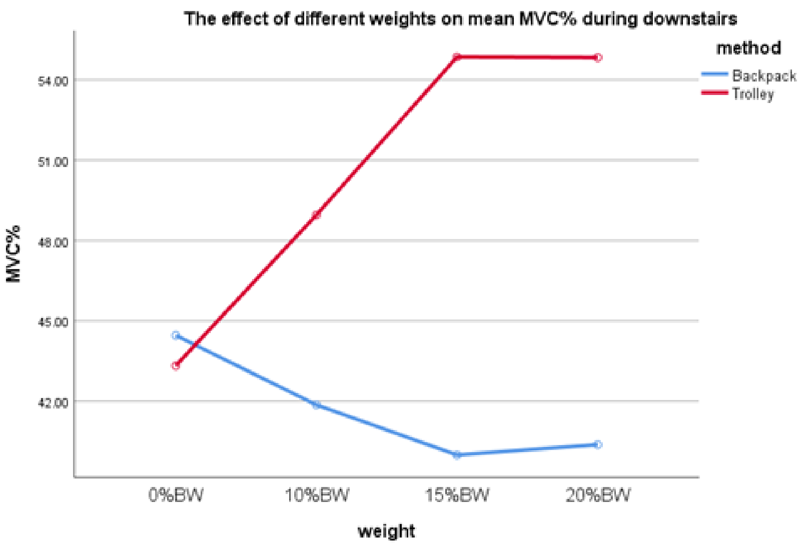
a. Computed using alpha = .05

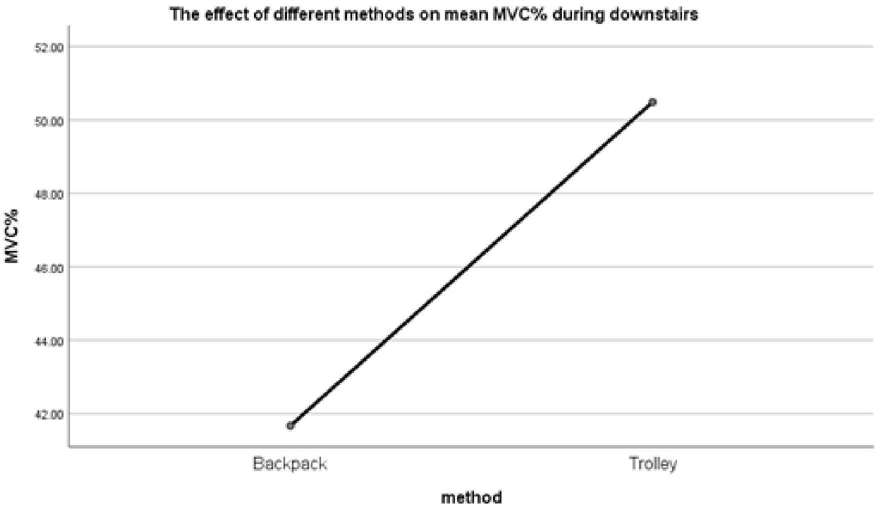


Result of **right gastrocnemius muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**3887.840**	**35.086**	**.000**	**.594**	**35.086**	**1.000**
weight	2.302	203.408	2.517	.082	.095	5.794	.519
method * weight	**2.270**	**937.520**	**10.686**	**.000**	**.308**	**24.259**	**.992**

a. Computed using alpha = .05

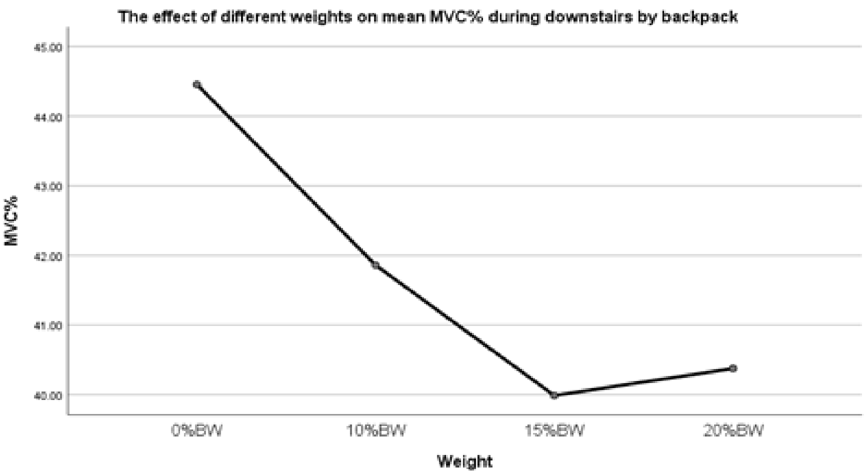




Result of **right gastrocnemius muscle** (mean MVC%) during **downstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**2.030**	**151.435**	**4.269**	**.019**	**.151**	**8.665**	**.723**

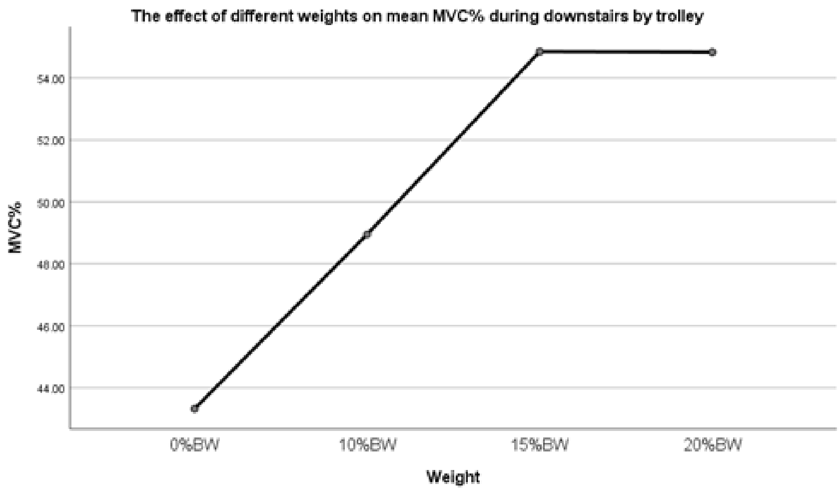
a. Computed using alpha = .05



Result of **right gastrocnemius muscle** (mean MVC%) during **downstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	**2.098**	**1091.017**	**7.309**	**.001**	**.233**	**15.336**	**.932**

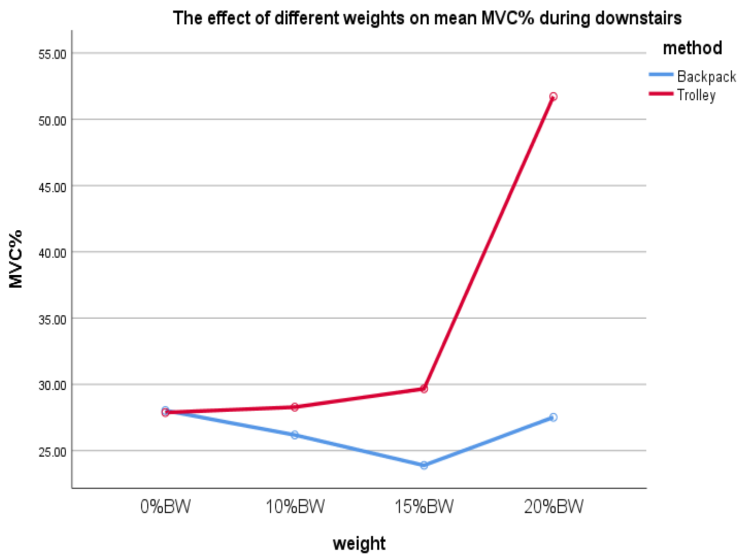
a. Computed using alpha = .05

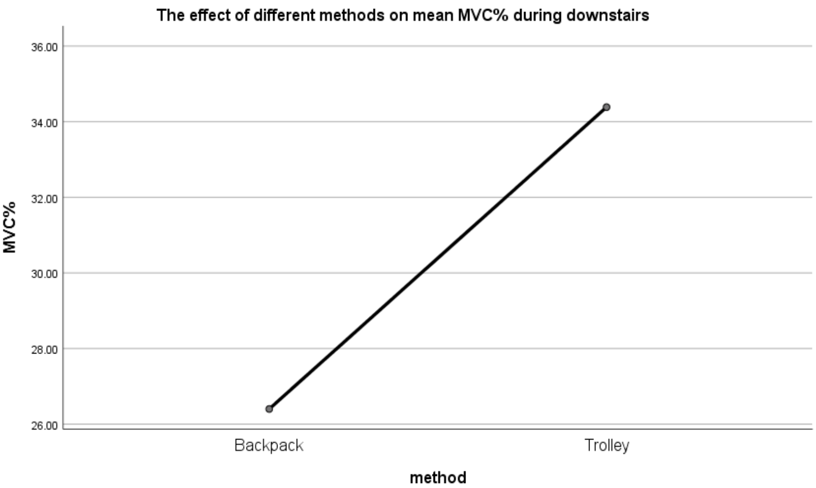


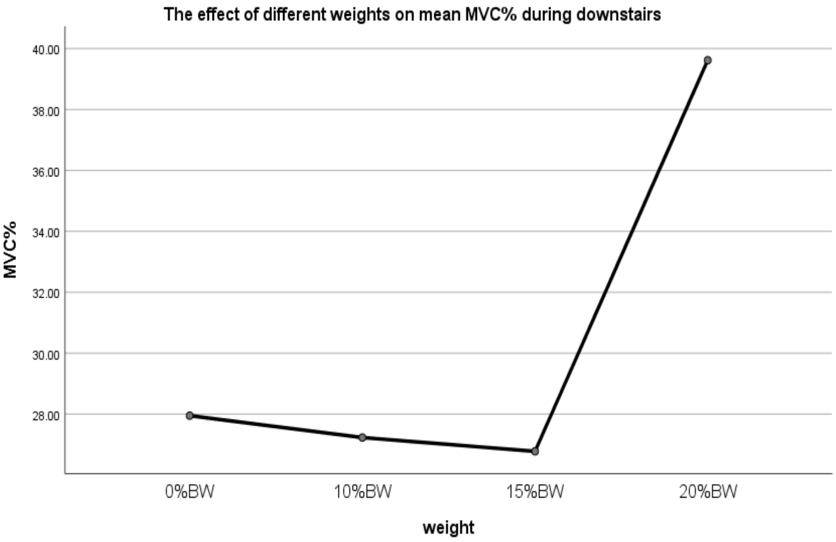
Result of **left semitendinosus muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**3186.473**	**18.298**	**.000**	**.433**	**18.298**	**.984**
weight	**1.231**	**4636.087**	**11.920**	**.001**	**.332**	**14.670**	**.949**
method * weight	**1.192**	**3867.902**	**10.649**	**.002**	**.307**	**12.691**	**.918**

a. Computed using alpha = .05



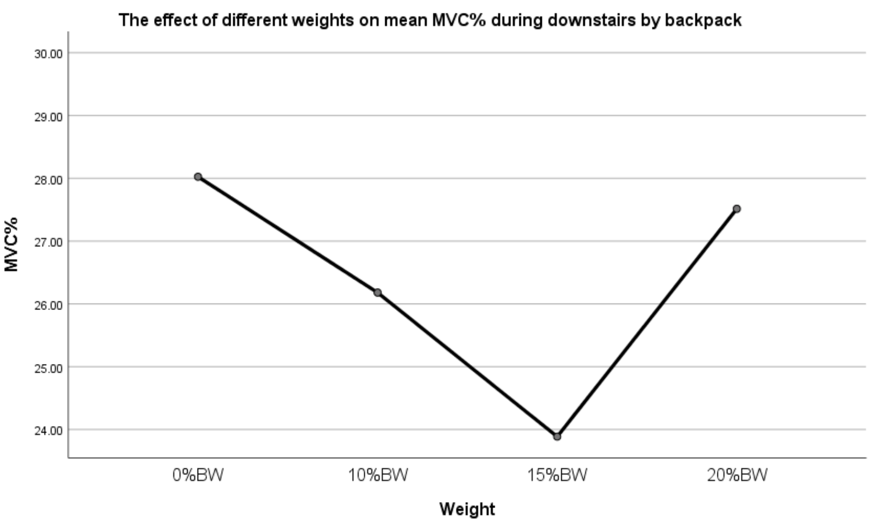




Result of **left semitendinosus muscle** (mean MVC%) during **downstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.563	163.934	1.478	.240	.058	2.310	.265

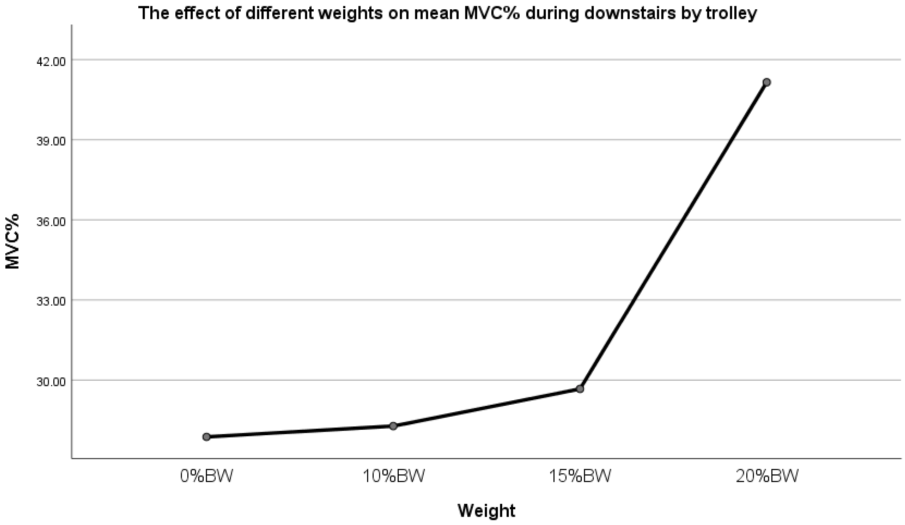
a. Computed using alpha = .05



Result of **left semitendinosus muscle** (mean MVC%) during **downstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.067	2806.453	2.015	.167	.077	2.150	.284

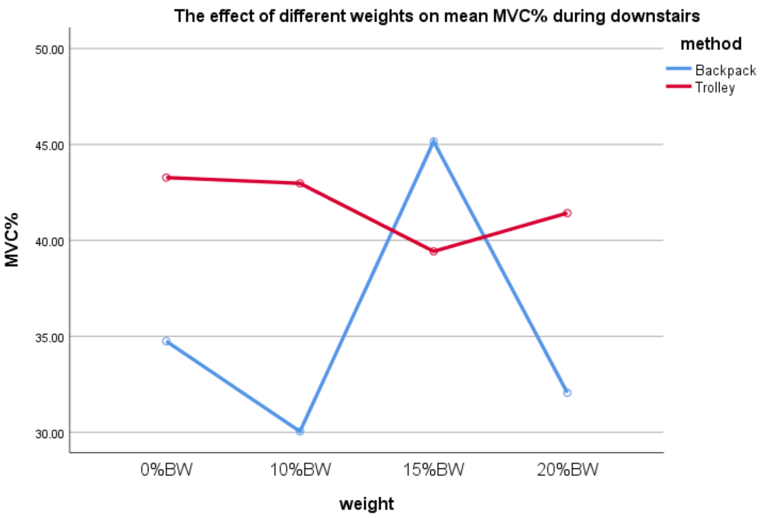
a. Computed using alpha = .05



Result of **right semitendinosus muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	1969.646	1.299	.266	.051	1.299	.195
weight	1.813	595.994	.427	.636	.017	.774	.112
method * weight	1.846	1374.458	.880	.414	.035	1.625	.186

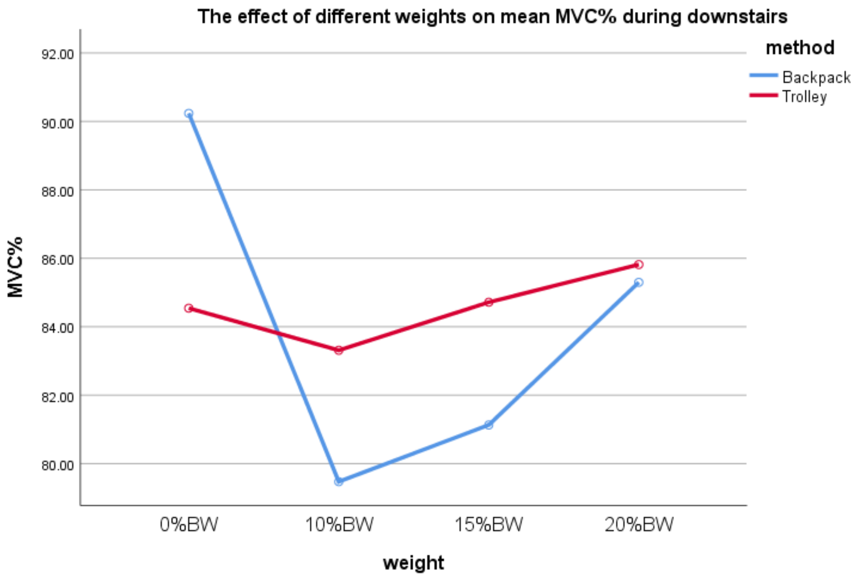
a. Computed using alpha = .05



Result of **left rectus femoris muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	15.861	.059	.810	.002	.059	.056
weight	1.917	560.275	1.287	.285	.051	2.467	.260
method * weight	2.400	307.505	1.561	.215	.051	3.745	.348

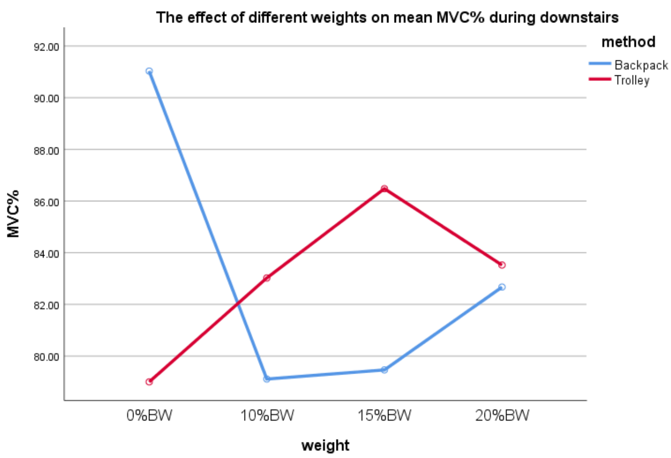
a. Computed using alpha = .05



Result of **right rectus femoris muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	.198	.001	.977	.000	.001	.050
weight	1.706	228.762	.436	.618	.018	.755	.112
method * weight	**1.937**	**1354.510**	**4.113**	**.024**	**.146**	**7.968**	**.691**

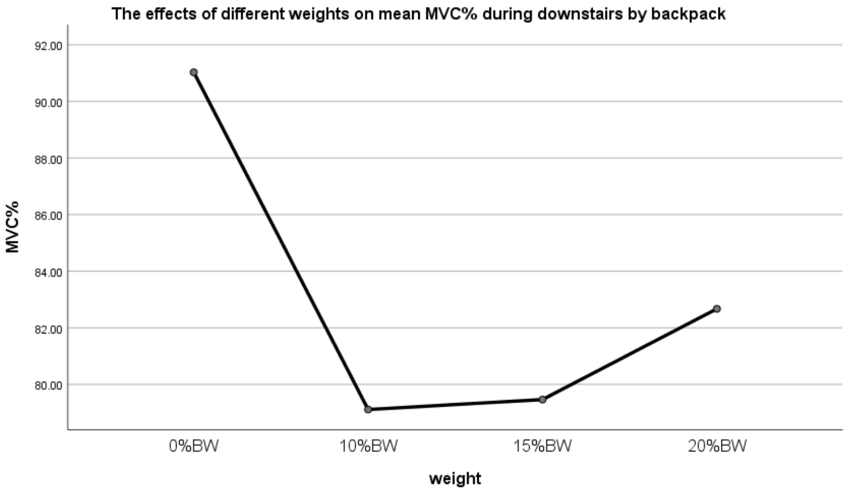
a. Computed using alpha = .05



Result of **right rectus femoris muscle** (mean MVC%) during **downstairs** by **backpack**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	1.407	1638.362	2.579	.106	.097	7.737	.612

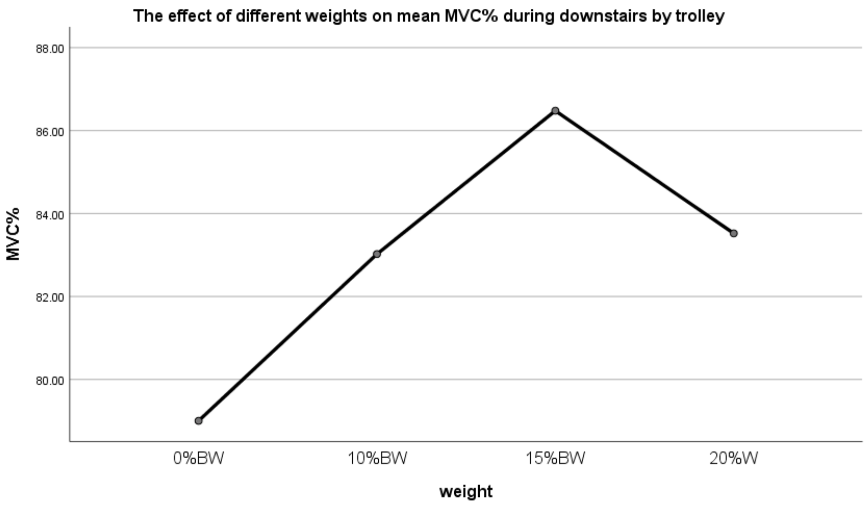
a. Computed using alpha = .05



Result of **right rectus femoris muscle** (mean MVC%) during **downstairs** by **trolley**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
weight	3	236.296	1.109	.351	.044	3.328	.288

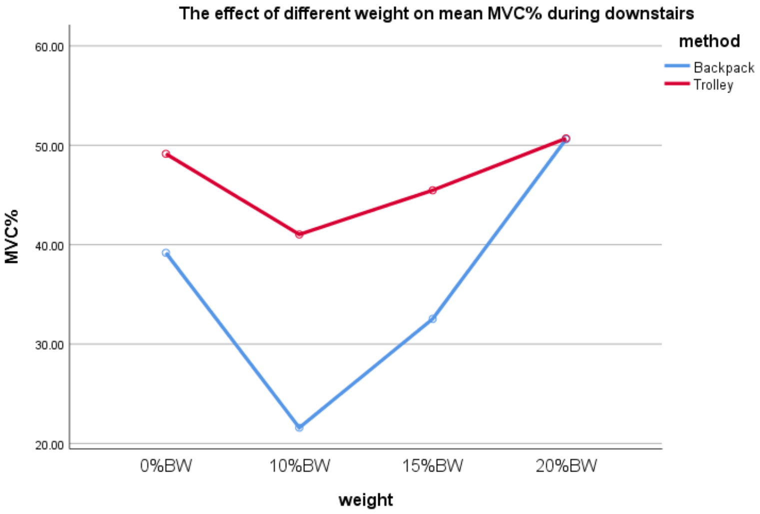
a. Computed using alpha = .05

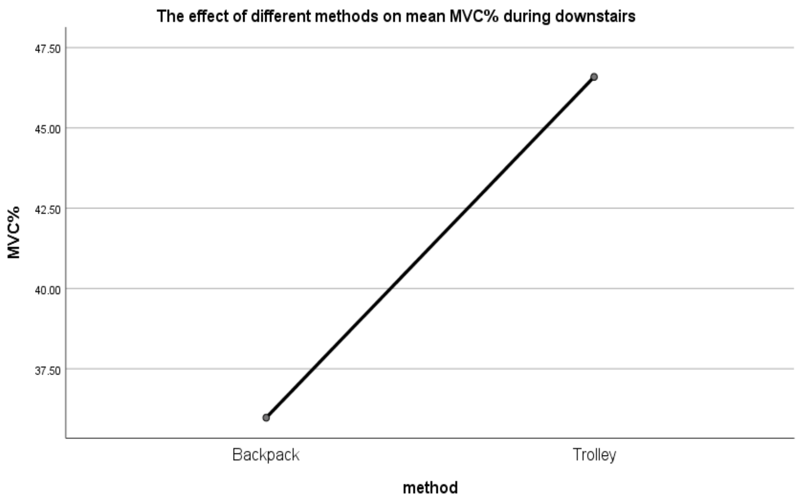


Result of **left lumbar erector spinae muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**5628.598**	**5.141**	**.033**	**.176**	**5.141**	**.586**
weight	1.323	7586.290	.750	.429	.030	.992	.145
method * weight	2.122	1145.995	.876	.428	.035	1.858	.197

a. Computed using alpha = .05

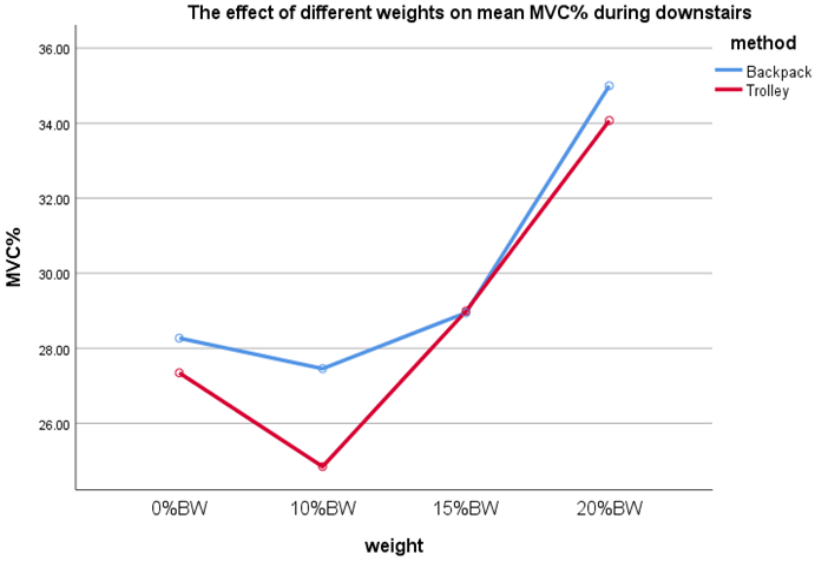


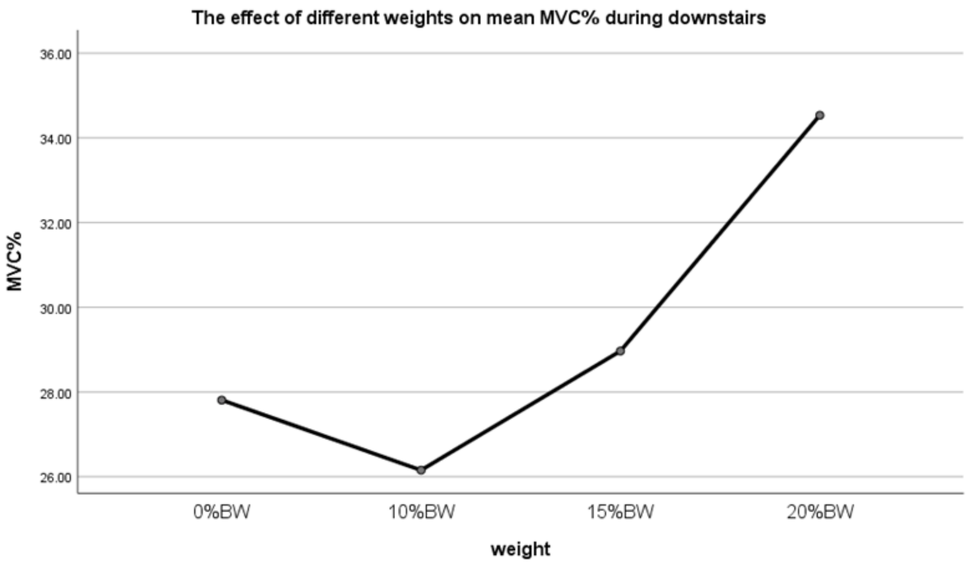


Result of **right lumbar erector spinae muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	61.045	.768	.390	.031	.768	.134
weight	**1.768**	**1120.605**	**6.474**	**.005**	**.212**	**11.447**	**.856**
method * weight	2.143	21.276	.347	.723	.014	.744	.104

a. Computed using alpha = .05

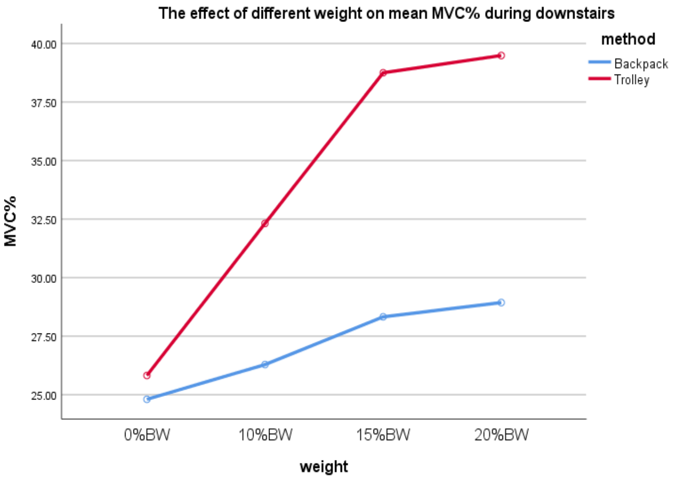


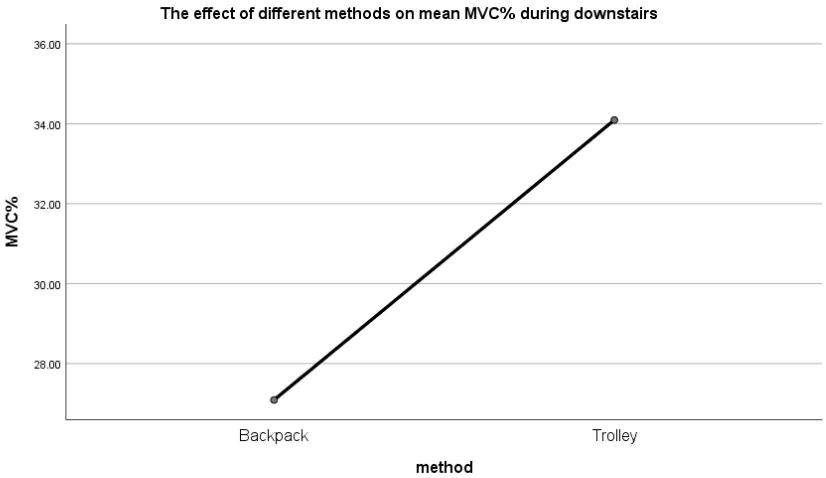


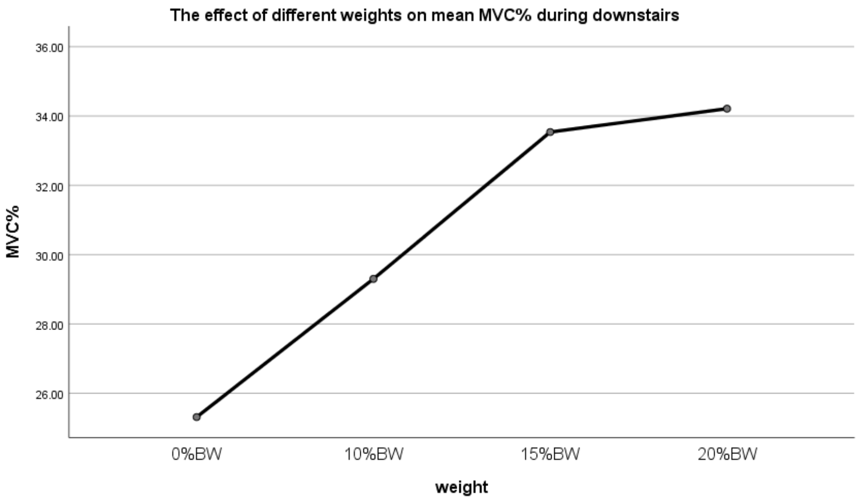
Result of **left abdominal muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	**1.000**	**2454.013**	**9.925**	**.004**	**.293**	**9.925**	**.856**
weight	**1.703**	**1506.676**	**10.158**	**.000**	**.297**	**17.295**	**.965**
method * weight	1.093	698.115	2.238	.145	.085	2.447	.314

a. Computed using alpha = .05


The effect of different weight on mean MVC% during downstairs
method
Backpack
Trolley
40.00
37.50
35.00
32.50
30.00
27.50
25.00
MVC%
0%BW
10%BW
15%BW
20%BW
weight


The effect of different methods on mean MVC% during downstairs
36.00
34.00
32.00
30.00
28.00
MVC%
Backpack
Trolley
method


The effect of different weights on mean MVC% during downstairs
36.00
34.00
32.00
30.00
28.00
26.00
MVC%
0%BW
10%BW
15%BW
20%BW
weight

Result of **right abdominal muscle** (mean MVC%) during **downstairs**

Source	df	Mean Square	F	Sig.	Partial Eta Squared	Noncentrality Parameter	Observed Power[a]
method	1.000	51.743	.830	.371	.033	.830	.141
weight	1.078	200.028	.275	.622	.011	.297	.081
method * weight	2.062	8.328	.242	.793	.010	.499	.086

a. Computed using alpha = .05