Title: Physiological profile of Asian elite youth soccer players

Running title: Physiological profile of youth soccer players

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Abstract

Objective: The purposes of this study are to provide information about the physiological characteristics of Asian elite youth soccer players (a) for strength and conditioning specialists to design training program based on players' physiological characteristics; and b) for coach to design an appropriate play tactic.

Design: Sixteen Chinese elite youth male players (height: 173 ± 5.2cm; weight: 64.2 ± 8.1kg; age: 16.2 ± 0.6year) from the U-17 national team participated in the following tests in the current study: (a) maximal vertical jump; (b) isokinetic muscular strength tests of knee joint at angular velocities of 60, 120, 180, 240, and 300deg/s; (c) maximal oxygen consumption (VO_{2max}); (d) one repetition maximum (1RM) strength test; and (e) 30m sprint.

Results: As compared to European and African players, Asian youth players have less jump height and shorter body height. They also have poor performance in isokinetic muscular strength of quadriceps and hamstrings (especially at high speed), VO_{2max}, 1RM strength test, sprint starts, and 20-30m sprints.

Conclusions: A specialised training in jumping performance, high-speed movement, muscular strength at high contraction speed, endurance running, short distance sprint (i.e. 5m), and 20-30m sprints are recommended for Asian elite youth soccer players (or players with similar physique and ability).

Keywords: football, strength, power, fitness

INTRODUCTION

Soccer (association football) is one of the most popular sports throughout the world, with more than 240 million players worldwide (38). The game consists of two 45 min halves, with a 15 min rest between halves. More than 90% of each game is performed by aerobic metabolism (4), and the average intensity is around the anaerobic lactate threshold (80 to 90% of maximal heart rate) (4, 17). It has been reported that during elite-level competition, players have to run about 10-12km in ~90 min (30). Furthermore, improved aerobic running ability of soccer players has been shown to improve their field performances, such as increased distance coverage, more involvement with the ball, similar technical performance despite significantly higher exercise intensity, and increased number of sprints (17). Besides aerobic ability, sprinting, strength and power are also important for soccer players to react quickly and ready for any body contact (30). Sprinting constitutes 1 to 11% of the total distance covered during a game (25, 33, 37), and a sprint bout occurs approximately every 90 seconds, each lasting an average of 2-4 seconds and corresponding to a maximum distance of approximately 30m (3, 29).

Physical fitness is also one of the important factors to differentiate players at the top level from those at the lower levels (32). Therefore, there have been numerous studies conducted to examine the physiological profiles and intervention effects among soccer players (8, 11, 13, 20, 23, 24). However, most of these studies investigated European, African, and American players, but it has been recently showed that the physical characteristics of players from various confederations are very different (39). Therefore it may not be appropriate to apply the findings of these previous studies on Asian players without knowing their physiological characteristics.

In recent years, there has been a rapid growth of soccer standards in Asia, which is demonstrated by the general increase in the world ranking of Asian countries between 2001 - 2006: Japan (from 40 to 15), Korea Republic (from 42 to 29), Saudi Arabia (from 38 to 33), China (from 76 to 73), and Hong Kong (from 123 to 117) (14). In 2002, Korea Republic ranked third runner-up in the FIFA World Cup. However, it has been reported that the body weight and body mass index (BMI) of Asian soccer players competing in 2002 and 2006 FIFA World Cups were significantly less than those players from other confederations (39). This implied that both the absolute body weight and the body weight under the same body height were less in Asian players, which may indicate a lower percentage of muscle mass, and eventually may affect and/or limit their field performances. Therefore, strength and weight training are necessary for Asian players in order to enhance the skill level and game standard. In order to achieve this purpose, we must first know the physiological weakness of these players by comparing them with players in foreign countries, but to our knowledge it is not available in the literature. For this reason, strength and conditioning specialist working with Asian players are facing difficulty to tailor–made specific training to strengthen players' physiological weakness. Therefore, the primary purpose of this study is to provide information about the physiological status of Asian elite youth soccer players to enable strength and conditioning specialists to design training program based on players' physiological characteristics. Furthermore, due to the possibility of physiological deficit of Asian players (39), we speculated that the selection of play tactics is limited/affected by their physiological characteristics. Therefore, the secondary purpose of this study is to provide information to coach to design an appropriate play tactic based on the physiological characteristics of Asian players.

METHODOLOGY

Experimental Approach to the Problem

In order to compare with previous studies and find out the physiological weakness of Asian players, we employed five tests that have been frequently used in soccer studies: (a) maximal vertical jump; (b) isokinetic muscular strength at various angular velocities; (c) maximal oxygen consumption (VO_{2max}); (d) 1RM strength; and (e) 30m sprint. The protocols were approved by the Clinical Research Ethics Committee. All players and their parents were properly informed of the nature of the study without being informed of its detailed aims. Each of the players and their parents signed the written consent prior to participation. Each player visited the experimental venue three times within one month. Maximal vertical jump and isokinetic muscular strength tests were conducted in the first visit; VO_{2max} test was conducted in the second visit; and weighted squat 1RM strength and 30m sprints were conducted in the third visit.

Maximal oxygen consumption (VO_{2max}) is a good indicator of aerobic fitness and has been using by researchers who intended to study soccer players' aerobic level (7-9, 21, 35). Furthermore, the ability to jump high (maximal) and sprint fast have been considered as important factors in order to compete in high level soccer (4), and have been used frequently by recent studies in soccer (7, 35, 36).

Maximal strength refers to the highest force that can be performed by the neuromuscular system during one maximum voluntary contraction (one repetition maximum – 1RM), whereas power is the product of strength and speed, and refers to the ability of the neuromuscular system to produce the greatest possible impulse in the shortest time period. The evaluation of muscle strength of the lower extremities in soccer has been performed using isokinetic peak torque (26, 42), where quadriceps/hamstrings strengths during concentric/eccentric concentrations at various angular velocities were examined. On the other hand, since it has been reported that strength tests employing free barbells would reflect the functional strength of soccer players more accurately (35), and 1RM squat has been reported to has significant relationship with acceleration, and movement velocity in soccer players (36). Therefore, in this study, we also employed a barbell 1RM squat test to examine players' leg strength.

Subject

Sixteen Chinese elite youth male soccer players (height: 173 ± 5.2cm; weight: 64.2 ±

8.1kg; age: 16.2 ± 0.6year) from the U-17 national team participated in the study. These players are members of the Champion of East Asian Football Federation Youth Tournament 2004. The federation comprises 10 football associations: Chinese FA, Chinese Taipei FA, Guam FA, Hong Kong FA, Japan FA, DPR Korea FA, Korea FA, Macau FA, Mongolian FA, and Northern Mariana Islands FA. The players had four soccer training sessions (each lasting for about 2 hours) and one formal competition per week. The training session consisted of technical and tactically training, and no strength (weight, and plyometrics) training was involved. Normally each training session has 15min warm-up, 30min technical training, 30min tactically training, 40min simulated competition, and 5min cool down.

Procedures

Maximal vertical jump

Prior to testing, each player underwent a 10 min warm-up period on a bicycle ergometer followed by static stretching of the lower limbs for 5min (10). The warm up ended with five semi-squat jumps to reach the players' maximal jump height, and a 30s rest in-between each jump was allowed.

One minute after the warm-up, the players underwent three semi-squat jumps with both hands fixed on the hips with a 2 min rest in-between jumps (7). This barefoot jump was conducted on a piezoelectric force platform (9281CA, Kistler, Germany). The best (highest) jump was selected for analysis (7). The vertical jump height was determined as the center of mass displacement calculated from the force development and measured body mass (36). The rate of force development was calculated using a previously described method (7).

Isokinetic muscular strength

The isokinetic muscular strength protocol (Figure 1) has been described in a previous study by Cometti et al. (10) and was measured using an isokinetic dynamometer (Cybex, Cybex International, Inc., New York, USA). The motor axis of the dynamometer was visually aligned with the axis of the knee joint of the preferred/dominant leg. The knee joint was adjusted when the leg was fully extended (knee angle = 0 deg) to avoid hyperextension of the joint. Torques were gravity-corrected at each joint angle where the gravity effect was greatest (31). After a standardised warm-up consisting of five sub-maximal (~50%) and one maximal concentric and eccentric contraction of the quadriceps and hamstring muscles at the experimental velocities (concentric: 60, 120, 180, 240, 300deg/s; eccentric: 60, 120deg/s), a 3 min rest was allowed. During data collection, three consecutive maximal contractions were performed at each angular velocity, and a 3 min rest period was allowed between each velocity. Only the highest peak torque values of the flexors (hamstring) and extensors (quadriceps) of the dominant leg were analysed.

The conventional Hamstrings/Quadriceps (H/Q) ratio is given as Hecc/Qecc and Hcon/Qcon at the corresponding angular velocities. In addition, we also employed the method by Aagaard et al. (1), ,in which an H/Q ratio is associated with knee flexion or extension

(Hcon/Qecc for knee flexion; Hecc/Qcon for knee extension;) at the same angular velocities (60 and 120deg/s).

****Insert Fig 1 here****

Maximal oxygen consumption

Upon arrival, nude body mass and height were measured before any running test. The initial speed of the VO_{2max} test was calculated from the VO_2-speed test (40). VO_{2max} was determined using an uphill incremental treadmill running test to exhaustion. The players were then asked to run at their own initial speed on a treadmill with 3.5% inclination. The inclination of the treadmill was increased by 2.5% every 3 min to a level that brought the player to exhaustion, which occurred within 10–15 min for all players. The following criteria were met by all players when testing VO_{2max}: (a) a levelling off of VO_2 despite treadmill speed increasing; (b) a respiratory gas exchange ratio >1.1; and (c) post-running blood lactate concentration >6 mmol/L (7, 8). Oxygen consumption was determined using a breath-by-breath system (MAX-II, Physio-Dyne, New York), and heart rate was monitored using a heart rate monitor (Sport Tester PE 4000, Polar Electro, Kempele, Finland). Oxygen consumption and heart rate data were recorded once every 20 seconds. Additionally, blood samples were drawn from the fingertip of the players 3.5 min after the VO_{2max} test (9), and blood lactate concentration was determined immediately by patented immobilised enzyme technology (Lactate analyser, Model 1500, YSI, Yellow Springs, OH).

Weighted squat 1RM strength

The semi-squat (90-degree at knee joint) movement included both the initial downward and then the upward phases (36). The players started with 10 repetitions at a low weight as warm-up, followed by a 3 min rest and then 3 to 6 trials with 5kg increments to reach their own 1RM (36). Each trial was separated with a 3 min rest to avoid fatigue.

30m sprint

The test was performed with soccer sportswear on an athletic track in order to ignore the unstable conditions of the grass pitch. The players were asked to complete a 20 min warm-up individually including several accelerations, and decide which foot they would have to set on the starting line for the sprint start from a standing position. The players had a 30m sprint with a stationary start (7, 24, 36). The starting pedal was positioned behind the starting line. The players had to start from a standing position placing their forward foot just behind the starting line and their rear foot on the pedal after having positioned the pedal according to their natural starting position. The timing started as soon as the foot of the player left the pedal. Speed was measured with an infra-red photoelectronic cell (Speedtrap II Wireless Timing System, Brower Timing System, Australia) positioned at 5m, 10m 15m, 20m, and 30m from the starting line at a height of 1m. There were 3 trials in total (24) and a 3 min recovery was allowed between each trial. The best (quickest) 30m sprinting time was selected for data analysis. Velocity (m/s) and acceleration (m/s/s) were calculated by dividing the distance by the time required during the specific distance interval.

Statistical Analysis

The software package SPSS 12.0 was employed in the data analysis. The level of significance was set at the alpha level of 0.05. One-way ANOVA was used to examine the differences between (a) peak torque of knee extensors and flexsors; (b) the peak torque of eccentric and concentric contractions; (c) conventional H/Q ratio during various angular velocities; (d) Aagaard et al. (1) proposed H/Q ratio during knee extension and flexion; (e) velocity during different distance intervals; and f) acceleration during different distance intervals. Pairwise comparison with Bonferroni adjustment was employed when there was a demonstrated significant difference in one-way ANOVA in order to keep the experiment-wise error rate at 0.05 (6). Data are presented as mean and standard deviation.

RESULTS

The results of maximal semi-squat vertical jump (Table 1), isokinetic muscular strength (Figure 2, 3, 4), time, velocity, and acceleration between each sprinting distance interval are shown below (Table 2). Moreover, maximal oxygen consumption was recorded as follows: 3857 ± 415 ml/min, 60.5 ± 5.4 ml/kg/min, and 170.4 ± 13.7 ml/kg$^{0.75}$/min; weighted squat 1RM strength was 116.3 ± 25.5kg; 30m sprint time was 5m (1.07 ± 0.05s), 10m (1.81 ± 0.05s), 15m (2.50 ± 0.07s), 20m (3.10 ± 0.09s), and 30m (4.32 ± 0.12s).

****Insert Table 1 here****

****Insert Fig 2 here****

****Insert Fig 3 here****

****Insert Fig 4 here****

****Insert Table 2 here****

DISCUSSION

Maximal vertical jump

Compared to a previous study that investigated the jumping ability of elite youth soccer players from the Tunisian national squad (7), we found that Asian elite youth soccer players generate less force, require longer time to reach their peak force, and have a shorter jump height. Specifically, the Tunisian soccer players have ~23% greater peak force, ~11% greater peak force (calculated based on player's body mass), ~35% shorter time to peak force, and 30% higher jump height. Moreover, the body height of the Asian players are on the average 5.6cm, 4.8cm, and 4.1cm shorter when compared with Finnish (27), Tunisian (7), and US players (34), respectively. Shorter jump height together with shorter body height may indicate that the Asian players might have a disadvantage in heading the ball. It has also been reported that headed goals account for 20% of all goals scored at the international level (2). Therefore, the Asian soccer players may be limited in their choice of game tactics, that is, more ground-passing with less emphasis on aerial attack. Alternatively, strength and conditioning specialists may emphasis their training to improve players' jump mechanics (by plyometrics exercise such as depth jump) and/or to strengthen players' leg muscles by equipment available in fitness room such as squat, leg press, leg extension, leg curl, and calf raise.

Isokinetic muscular strength at various angular velocities

The peak torques of knee extensors were higher than those of knee flexors at each of the angular velocities ($P < 0.01$) (Figure 2). Moreover, for the same muscle group, the peak torques developed during eccentric contractions were higher than those during concentric contractions ($P < 0.01$). Since there is no previous study that reported the isokinetic muscular strength of elite youth soccer players, we compared the results with French Division 2 soccer players who were ~23-year-olds (10). Asian soccer players have a lower peak torque for knee extensors when compared with the French Division 2 players. Their Qcon peak torques were 13%, 8%, 17%, 20%, and 25% lower than those of the French players at the five angular velocities from slow to fast. In addition, the Hcon peak torque of the Asian players was 22%, 24%, 22%, 28%, and 35% lower than those of the French players at the five angular velocities from slow to fast. Also, the Qecc peak torque of the Asian players was 12% (at 60deg/s) and 14% (at 120deg/s) lower, and their Hecc peak torque was 25% (at 60deg/s) and 33% (at 120deg/s) lower compared with those of the older French players

When the angular velocity was increased progressively from 60deg/s to 300deg/s (Figure 2), Qcon peak torque decreased from 195N.m to 104N.m (~47% reduction), while Hcon peak torque decreased from 115N.m to 66N.m (~43% reduction). The phenomenon of decreased peak torque when angular velocity is increased is in agreement with previous studies (10, 28).

However, as reported in a previous study (10), when the angular velocity was increased from 60deg/s to 300deg/s, the Qcon peak torque was reduced by 39% only, and the Hcon peak torque was reduced by 33%. This means that the French players were more capable of maintaining muscular strength at a high speed as compared to the Asian players. Therefore, strength and conditioning specialists are suggested to design a program that first focus on the strength development, and in latter training phase transfer the strength (at normal movement speed) into power (at fast movement speed).

The conventional H/Q ratio in this study ranged from 0.6 to 0.7 (Figure 3), and no significant difference of this ratio was found between various angular velocities ($P > 0.05$). Fowler and Reilly (15) studied professional soccer players who have musculoskeletal injury and reported that the H/Q ratio of the injured leg (~0.5) is about 0.13 lower than that of the uninjured leg (~0.63). Their study supports the belief that an H/Q ratio lower than 0.6 may predispose a soccer player to injury, and in our study, the Asian players are above the injury risk. Furthermore, it has been reported that players at a higher competition and skill level have a higher value of H/Q ratio (10), and the H/Q ratio ranges from 0.72 to 0.83 in male players at professional, semiprofessional, and varsity levels (41). This may imply that an improvement in hamstring strength is needed in Asian players since the hamstrings are not routinely stimulated during traditional soccer practice (12).

The H/Q ratio proposed by Aagaard et al. is higher in knee extension than in knee flexion ($P < 0.01$) (Figure 4). This H/Q ratio significantly increased from 0.8 to 1 when the angular velocity during knee extension was increased from 60deg/s to 120deg/s ($P < 0.01$), while it is ~0.5 during knee flexion at 60deg/s and 120deg/s. The results are almost the same as the previous study of French Division 1 and Division 2 players (10). This supports the idea that in soccer, the knee extension plays an important role in jumping and ball kicking, while knee flexion controls the running activities and stabilises the knee during turns or tackles (16).

Maximal oxygen consumption

Compared with players of similar age in other countries (Table 3), the absolute value of VO_{2max} (ml/min) among Asian players was 3.7% to 15% lower. However, because the Tunisian, Scottish, and Finnish players were 6.3 - 7.1kg heavier than the Asian players, the differences between these players and the Asian players were smaller in terms of oxygen consumption relative to body weight (ml/min/kg, and $ml/kg^{0.75}/min$). Since the absolute and relative VO_{2max} of Asian players were lower, we postulated that this would impair their field performance, as a previous study reported that an increased aerobic capacity is associated with more involvement of the ball and increased number of sprints in competition (17). Therefore, we suggest strength and conditioning specialists to develop players' aerobic capacity by a specific dribbling training (19) at the interval of 4set x 4min (intensity ~ 90-95% of player's maximal heart rate) , with a 3min recovery jog at 70% of player's maximal heart rate in-between set (24). It has been shown that by performing this training twice per week for 10 weeks improved elite youth players' VO2max of 10% (from 63.4 to

69.8ml/min/kg) (24).

****Insert Table 3 here****

Weighted squat 1RM

Maximal strength is one basic quality that influences power performance; an increase in maximal strength is usually connected with an improvement in relative strength and therefore with the improvement of power abilities. A significant relationship has been observed among 1RM, acceleration, and movement velocity (18). By increasing the available force of muscular contractions in appropriate muscles or muscle groups, acceleration and speed in skills critical to soccer such as turning and changing pace may improve (5). It has been reported that the Scottish and Greek players achieved 129kg and 140kg in weighted squat 1RM (22, 24), which were 11% and 21% higher than those of the Asian players who participated in this study. Therefore, we postulated that Asian players may not perform soccer skills such as turning and changing pace, and the same was the case for players in Scotland and Greece. Therefore, strength training for the leg muscles is strongly encourage to incorporate into the yearly training program of Asian players.

30m sprint

Since there is no complete information available in the literature regarding the sprint time over 5m, 10m, 15m, 20m, and 30m, a weighted average sprint time was calculated based on a previous review of 12 related articles, which included professional, semi-professional, amateur, and elite youth soccer players (30). The results of previous studies (30) showed that the average sprint time was 5m (1.05s), 10m (1.84s), 15m (2.51s), 20m (3.08s), and 30m (4.26s). Compared with the results reported in previous reviews (30), the Asian players sprint 1.7% and 0.4% faster at 10m and 15m, but sprint 1.9%, 0.6%, and 1.4% slower at 5m, 20m, and 30m. When considering the time, velocity, and acceleration with regard to each distance interval (Table 2), the velocity of Asian players increased from 0m to 20m and, a huge deceleration (> 50%) occurred from that point onwards. This suggests that Asian players may have an improper starting technique or lack of muscle power to start a sprint from a static position over a very short distance (i.e., 5m). Furthermore, the huge deceleration that occurred between 20m and 30m might be the result of insufficient training within this distance or an adaptation to the style of play in competition, where Asian players rarely sprint more than 20m in one bout. We suggest strength and conditioning specialists to focus on players' speed endurance training, as well as the technique for running start.

Practical Application

We speculated that the playing style and game tactics of Asian soccer players, owing to the possibility of less muscle composition, may be affected by their weakness in generating muscular strength and power. Our study's results showed that Asian youth players had 30% less jump height as compared with Tunisian players and that this, together with the shorter body height of Asian players, would impose a limitation on the playing style to retain the ball on the ground rather than focusing on an aerial attacking strategy. In addition, our study's results showed that the Asian elite youth soccer players perform poorly in the isokinetic muscular strength tests of the quadriceps and hamstrings (especially at a high speed), maximum oxygen consumption, weighted squat 1RM, sprint starts, and sprints at the distance between 20-30m. Therefore, we suggest that Asian players (or players with similar physique and ability) focus their training on (a) ground passing in order to optimise attacking play, (b) off-the-ball running to make more spaces and choices for the pass, (c) high-speed movement and muscular strength at a high angular velocity which may improve kicking and shooting power, (d) endurance running ability in order to increase the distance covered and maintain the performance in the second half during competition, and (e) sprint ability in order to counter-attack the offside trap, thus leading to more goal-scoring opportunities.

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Figure Legends

Figure 1. Protocol of isokinetic muscular strength.

Figure 2. Peak torque developed for knee extensors (black bars) and knee flexors (grey bars), from 120deg/s eccentric to 300deg/s concentric. Values are means and SD.

Note. Qecc=Quadriceps eccentric contraction; Qcon=Quadriceps concentric contraction; Hecc=Hamstrings eccentric contraction; Hcon=Hamstrings concentric contraction.

* The peak torque of knee extensors was significantly higher than that of knee flexors ($P < 0.01$) at each angular velocity, and for the same muscle group, peak torque during eccentric contraction was higher than that during concentric contraction ($P < 0.01$).

Figure 3. Conventional H/Q ratio based on peak torque. Negative angular velocity: Hecc/Qecc; positive angular velocity: Hcon/Qcon. Values are means and SD.

Figure 4. H/Q ratio proposed by Aagaard et al. based on the peak torque. Knee flexion: Hcon/Qecc; knee extension: Hecc/Qcon. Values are means and SD.

* The H/Q ratio was significantly higher in knee extension ($P < 0.01$) compared to knee flexion; for knee extension, H/Q ratio was significantly higher when the angular velocity is increased from 60deg/s to 120deg/s.

Warm up

Type of contraction	Angular velocity (deg/s)	Number of trial
Concentric of Quadriceps Concentric of Hamstrings	60 120 180 240 300	5 sub-maximal ↓ 30s rest ↓ 1 maximal ↓ 30s rest
Eccentric of Quadriceps Eccentric of Hamstrings	60 120	

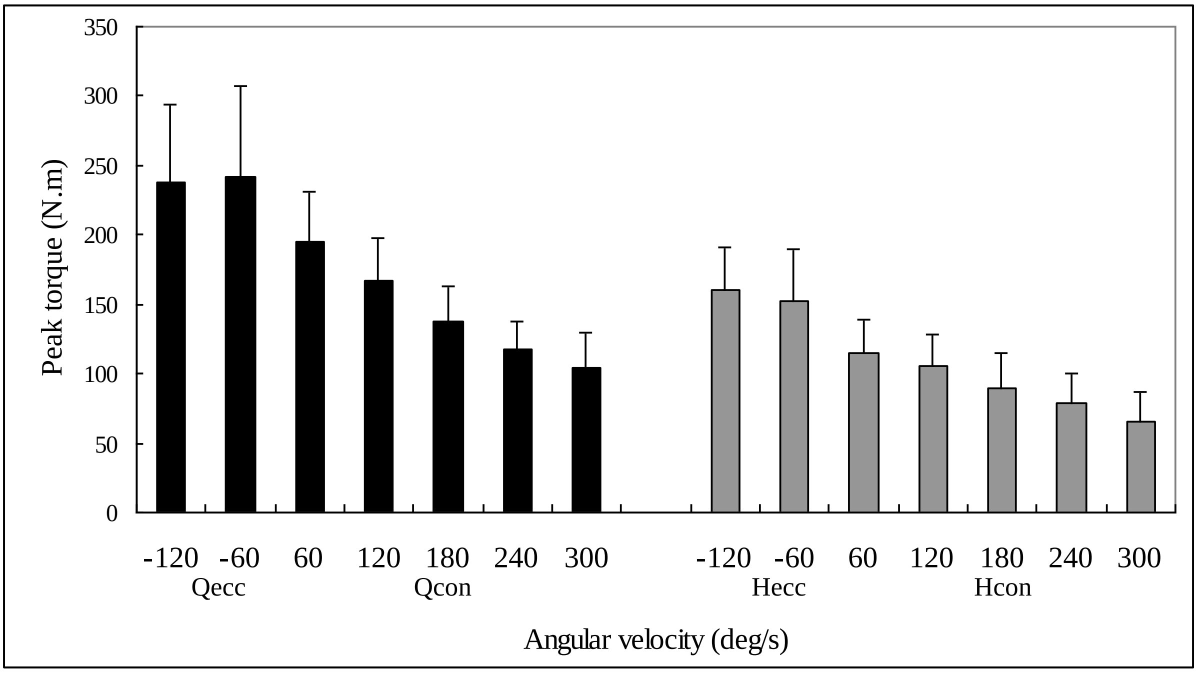
↓

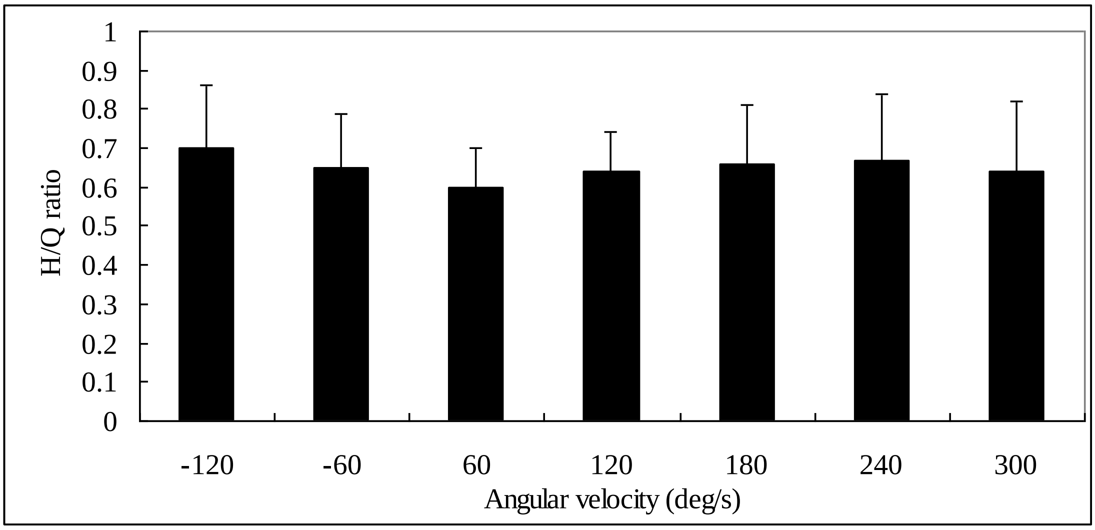
3min rest

↓

Test

Type of contraction	Angular velocity (deg/s)	Number of trial
Concentric of Quadriceps Concentric of Hamstrings	60 120 180 240 300	3 maximal ↓ 3min rest
Eccentric of Quadriceps Eccentric of Hamstrings	60 120	


350
300
250
200
150
100
50
0
Peak torque (N.m)
-120
-60
60
120
180
240
300
-120
-60
60
120
180
240
300
Qecc
Qcon
Hecc
Hcon
Angular velocity (deg/s)


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
H/Q ratio
-120
-60
60
120
180
240
300
Angular velocity (deg/s)

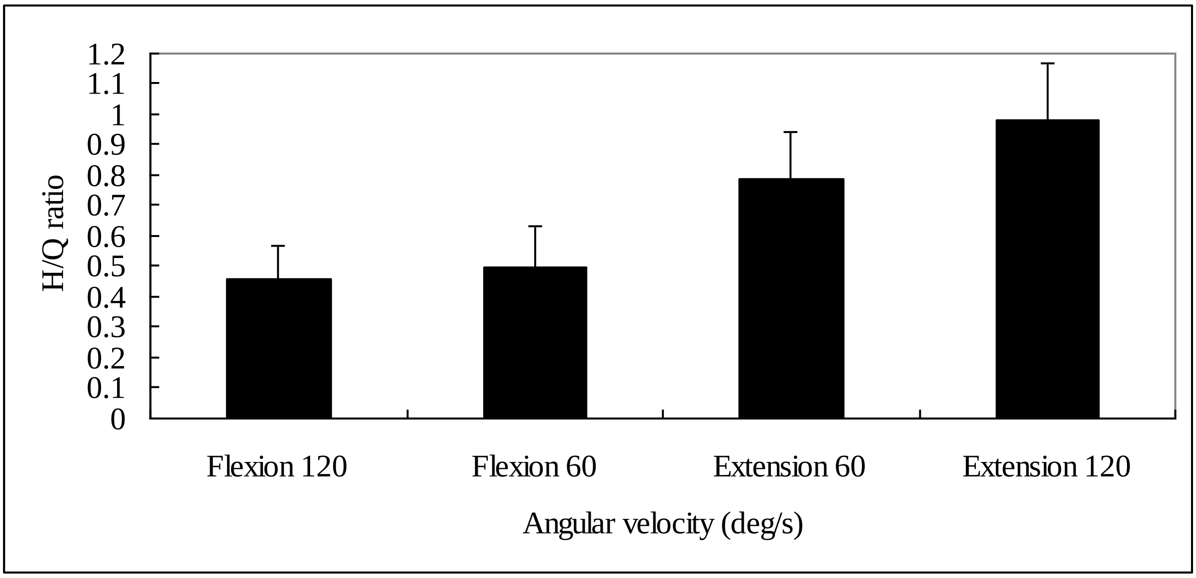

1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
H/Q ratio
Flexion 120
Flexion 60
Extension 60
Extension 120
Angular velocity (deg/s)

Table 1. Parameters during maximal semi-squat vertical jump (upward phase only) measured by force platform.

	Peak jumping force (N)	Peak jumping force (N/kg)*	Time to peak force (s)	Total flight time (s)	Jump height (cm)	Rate of force development (N/s)
Mean	1518.79	23.84	0.26	0.57	39.33	4751.81
SD	263.71	3.01	0.12	0.03	4.82	1187.16

* Peak jumping force in terms of the player's own body mass (kg).

Table 2. Sprint time, mean velocity, and acceleration between each distance interval.

	0m – 5m	5m – 10m	10m – 15m	15m – 20m	20m – 30m
Time (s)	1.07 (0.05)	0.74 (0.04)	0.69 (0.03)	0.60 (0.03)	1.22 (0.05)
Mean velocity (m/s) [a]	4.68 (0.21)	6.78 (0.35)	7.27 (0.30)	8.29 (0.40)	8.20 (0.32)
Acceleration (m/s^2) [b]	4.39 (0.39)	9.22 (0.94)	10.59 (0.87)	13.78 (1.31)	6.73 (0.52)

[a] Significant difference between all comparisons at $P < 0.01$, except for 15m-20m vs 20m-30m ($P > 0.05$).

[b] Significant difference between all comparisons at $P < 0.01$.

Table 3. Comparison of VO_{2max} between elite youth players among different countries.

	Age (year)	Weight (kg)	VO2max		
			ml/min	ml/kg/min	ml/kg$^{0.75}$/min
Asian	16.2	64.2	3857	60.5	170.4
Tunisian (7)	17.5	70.5	4300 (11%)	61.1 (1%)	177 (4%)
Scottish (24)	16.9	70.6	4450 (15%)	63.4 (5%)	183 (7%)
Finnish (27)	17.5	71.3	4000 (3.7%)	56 (-7.4%)	163 (-4.3%)

Note. Parenthesis showed the percentage difference when compared with Asian elite youth players.