Submitted: 03 October, 2020 Accepted: 16 December, 2020 Published: 08 January, 2021 DOI:10.31083/jomh.v17i1.335

JOMH Journal of Men's Health

Original Article

Relationship between anaerobic power and isokinetic trunk strength in college male soccer players

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Abstract

Background: Although anaerobic power affects soccer performance, the relationship between anaerobic power and core strength in soccer players has not been well studied. The aim of our study was to investigate the relationship between anaerobic power and core strength. **Methods**: The subjects were 31 college male soccer players. Their physical characteristics, anaerobic power (Wingate anaerobic test: WAnT), and core strength (isokinetic trunk strength test; ITST) were measured. To describe the effect of core strength on anaerobic power, the Pearson correlation coefficient and multiple regression analysis were conducted. **Results**: A significant relationship between the WAnT peak power (PP) and variables of ITST was observed (vs. trunk extension strength; TES: r = 0.629, vs. trunk flexion strength; TES: r = 0.507, vs. trunk extension power; TEP: r = 0.411, and vs. trunk flexion power; TFP: r = 0.555). We also found a relationship between the WAnT mean power (MP) and variables of ITST (vs. TES: r = 0.654, vs. TFS: r = 0.559, vs. TEP: r = 0.468, and vs. TFP: r = 0.720). The variables of ITST affecting WAnT PP were TES ($P < 0.001$) and TFP ($P < 0.001$). The explanatory power of these variables was 59.7% (R^2 = 0.597). The variables of ITST affecting WAnT MP were TFS ($P < 0.001$) and TSE ($P < 0.001$). The explanatory power of these variables was 72.7% (R^2 = 0.727). **Conclusion**: The results of our study showed that isokinetic trunk strength significantly associated with the WAnT peak and mean power.

Keywords

Anaerobic power; Wingate test; Core strength; Isokinetic trunk strength; Soccer

1. Introduction

Soccer games require intermittent physical activity of varying intensity. Intermittent activities such as sprints, jumps, and tackles are crucial factors for a successful performance [1].It is especially essential to accelerate the body during short movements, occupying the ball, or competing for possession in the air [2]. These activities depend on the anaerobic power [3]. Anaerobic power refers to the ability of the neuromuscular system to generate explosive energy in a short period of time. Explosive exercise requires rapid energy production, which occurs with anaerobic metabolism (ATP-PC and lactic acid system).

Therefore, it is desirable to have anaerobic power in addition to high aerobic capacity for better performance. The Wingate anaerobic test (WAnT) is one of the tests that could provide valid and accurate information on anaerobic power [4]. WAnT is frequently used for the evaluation of anaerobic power in soccer players [5, 6]. A previous study using WAnT showed that main players had a better peak power than the candidate players in elite soccer players [7]. Another study reported differences in the anaerobic power between elite and non-elite soccer players [1].

Meanwhile, core muscle strength is a key factor in maximizing the lower extremity balance and movement performance while stabilizing the spine and trunk during exercise

[8]. The core areas are composed of related muscle groups that support each other and require the coordination of the upper and lower extremities. Powerful core strength has been reported to not only make the body more energy efficient, but also to facilitate the transfer of force [9]. Core training has been shown to have a positive impact on sports performance [10].

Trunk muscle strength is one of the representative methods of evaluating core muscle strength, [11]. which is considered an important factor for sports performance [12]. Especially, measurements of peak torque of trunk extension and flexion in the isokinetic trunk muscle strength is commonly used to estimate trunk muscle strength [13]. Moreover, the reliability of the measurement of isokinetic trunk muscle strength for core muscle strength evaluation has been demonstrated [11]. However, the relationship between anaerobic power and isokinetic trunk muscle strength has not yet been elucidated.

Appropriate training strategies are essential for improving the athlete's performance [14]. The correlation between anaerobic power and isokinetic trunk muscle could help in the efficient organizing of training. Therefore, the purpose of our study was to examine the relationship between anaerobic power and isokinetic trunk muscle in soccer players.

TABLE 1. Physical characteristic of the subjects.

Variables	Group N = 31 Mean ± SD
Height (cm)	174.4 ± 6.5
Weight (kg)	68.7 ± 7.2
BMI (kg/m^2)	22.5 ± 1.4
Muscle mass (kg/m^2)	34.2 ± 3.9
Body fat (%)	12.5 ± 3.2
Age (years)	20.1 ± 1.0
Experience (month)	110.2 ± 17.7

2. Methods

2.1 Participants

The participants of this study were 31 college male soccer players who visited the J Sports Science Center to assess their physical fitness in November 2019. They were all members of one team and participated in the experiment at the same time. They were measured for physical characteristics (height, weight, muscle mass, and body fat percentage), anaerobic power, and core strength. Their physical characteristics are shown in Table 1. All participants signed an informed consent form before the start of the measurements. The study participants agreed to participate in our study after completely understanding its purpose and methods, in accordance with the ethical principles of the Declaration of Helsinki.

2.2 Measurement of physical characteristics

The physical characteristics were height (cm), weight (kg), muscle mass (kg), and body fat (%). The height was measured using a stadiometer (BSM-370, Biospace, Korea) and the measured value was recorded up to 0.1 cm. The weight, muscle mass, and body fat were measured using a body composition analyzer (Inbody-770, Biospace, Korea) after the measurement of height.

2.3 Isokinetic trunk strength

The core strength was evaluated using the isokinetic trunk strength test (ITST). ITST was conducted using isokinetic dynamometers (Humac Norm, CSMi, Stoughton, MA, USA). The motor axis of the dynamometers was visually aligned with the anterior iliac crest. ITST was performed with the participant in a standing position; stabilization clips were secured across the shoulder, thigh, and under the knee. The trunk extension strength (TES) and trunk flexion strength (TFS) were measured at 30° × s-1 (3 repetitions). At 180° × s-1 (3 repetitions), the trunk extension power (TEP) and trunk flexion power (TFP) were measured. For maximum strength and power, the participants were verbally encouraged during the measurement. Before starting the ITST, participants were allowed 2 trials. The trunk extension and flexion strength utilized the peak torque (N·m). The total work (J) was used to calculate the trunk extension and flexion power.

2.4 Anaerobic power

The Wingate anaerobic test (WAnT) was used to evaluate the anaerobic power. The WAnT was conducted using a cycle ergometer (894 E, Monark, Sweden). The WAnT was performed referring to widely adopted standard methods [15]. The Handle and seat heights were adjusted according to each participant's satisfaction. The maximum revolutions per minute (RPM) of each participant was measured via a 10 s pretest before the start of the 30 s WAnT. The resistance for the WAnT was set to 7.5% of the weight of each participant. The participants were instructed before the WAnT to pedal as fast as possible and were energetically encouraged during the test. When the RPM reached the maximum value, the resistance was applied and subjects continued pedaling as fast as possible for 30 s. The peak power (Watt), mean power (Watt), and fatigue index (%) were calculated automatically by the WAnT program. Additionally, the relative peak power (W/kg) and mean power (W/kg) were calculated using the weight of each participant.

2.5 Statistical analysis

All the variables measured in our study were analyzed using SPSS version 23.0 for Windows (SPSS, Inc., Chicago, IL, USA). The Pearson's correlation analysis was performed to investigate the factors affecting the anaerobic power. Subsequently, stepwise multiple regression analysis was performed only on those factors found to be significantly different in the correlation analysis. The mean and standard deviation (SD) of all variables were calculated and are presented; all statistical significance (α) was set at 0.05.

3. Results

3.1 Results of anaerobic power and core strength variables

The anaerobic power and core strength variables of college male soccer players were WAnT peak power (PP), WAnT mean power (MP), WAnT fatigue index (FI), relative PP (RPP), relative MP (RMP), trunk extension strength (TES), trunk flexion strength (TFS), trunk extension power (TEP), and trunk flexion power (TFP). Table 2 shows the results of each variable.

TABLE 2. The results of anaerobic power and core strength variables.

Variables		N = 31 Mean ± SD
Anaerobic power	Peak power (W)	642.5 ± 111.4
	Mean power (W)	487.4 ± 78.8
	Fatigue index (%)	55.4 ± 6.9
	Peak power per weight (W/kg)	9.3 ± 1.0
	Mean power per weight (W/kg)	7.1 ± 0.6
Core strength	Trunk extension strength - 30° (Nm)	258.0 ± 51.7
	Trunk flexion strength - 30° (Nm)	189.7 ± 24.4
	Trunk extension power - 120° (Nm)	245.0 ± 48.9
	Trunk flexion power - 120° (Nm)	224.4 ± 38.3

3.2 Correlation coefficients between the WAnT and ITST variables

The results of Pearson's correlation coefficient analysis between the WAnT and ITST variables are shown in Table 3. Significant correlations between PP and ITST variables were found including TES (r = 0.629), TFS (r = 0.507), TEP (r = 0.411), and TFP (r = 0.555). MP was calculated with the values of TES (r = 0.654), TFS (r = 0.559), TEP (r = 0.468), and TFP (r = 0.720). In the RPP, TES (r = 0.457) showed a significant correlation. In the case of RMP, TES (r = 0.494) and TFP (r = 0.616) showed significant correlations. FI was not found to be significantly correlated.

3.3 Multiple regression analysis of ITS variables affecting WAnT

The results of the multiple regression analysis of ITS variables affecting WAnT are shown in Tables 4 and 5. The significant predictors of PP were TES ($P < 0.001$) and TFP ($P < 0.001$); these variables accounted for 59.7% of the explanatory power ($R^2 = 0.597$). The predictors of MP were TFP ($P < 0.001$) and TES ($P < 0.001$); the explanatory power of these variables was 72.7% ($R^2 = 0.727$).

4. Discussion

In our study, the relationship between various trunk muscle strength factors and anaerobic power factors was found through correlation analysis. In addition, through multiple regression analysis, it was possible to find a factor that is deeply related to the anaerobic power factors among various trunk strength factors. Specifically, the trunk extensor strength was more closely related to the WAnT PP than other strength factors. The WAnT MP had a greater relationship between trunk flexor power and extensor muscle strength than other strength factors. These results can help coaches and athletes more effectively plan their anaerobic training program.

The variables that significantly affected the WAnT PP were TES and TFS ($R^2 = 59.7$, $P < 0.001$). The PP refers to the largest output value during the first 5s in WAnT [4]. ATP resynthesis during maximal exercise in less than 5 s is provided by the degradation of creatine-phosphate [16]. In order to achieve the maximum power, the muscles of the whole body must contract in a strong manner; the trunk muscle appears to play an important role during peak power. In a previous study, an in situ EMG amplitude analysis reported that activation of the trunk flexor muscles was significantly greater in the put-off phase; additionally, the trunk flexor was shown to be an important contributor to power exertion (jump ability) [17]. In addition, Okubo *et al.* (2013) [18] reported that the rectus abdominis and external abdominal muscles were activated just before the jump; the transverse abdominis muscle was activated during the jump. This implies the importance of trunk flexion in exerting power.

Another study determined that the hip extensor (gluteus maximus) and flexor (psoas) were activated during the downstroke at maximum cycle exercise [19, 20]. It was observed that most of the power was generated in the hip joint rather than in the knee joint. Moreover, it was shown that the hip extensors were 2 times larger than the knee extensor during the downstroke [21, 22]. This means that the hip extensors are important in exerting peak power. As such, it is understood that the trunk extensor and flexor muscles form a stable core and the forces generated in the lower or upper extremities seem to help deliver greater power without energy loss [23]. These results suggest that in order to improve the peak power, which is important for soccer players, it is necessary to focus on the training to improve the strength of the trunk flexors and extensors as well as conventional core stabilization exercises.

Athletes who require the repetition of a short maximum workout are energized by an ATP-PC and anaerobic glycolytic energy system [24]. The MP in WAnT is the average power output for 30 s [4]. In this study, the factors of ITST that had a significant effect on the MP were TFP and TES ($R^2 = 72.7$, $P < 0.000$). This means that the TFP and TES are important in the ability to supply energy without oxygen from maximum exercise for 30 s. Previous studies have suggested that changing the posture of the trunk during weight-bearing activities may affect the moment distribution between the lower limb joints [25, 26]. Teng & Powers (2016) [27] reported that upright trunk posture is overly dependent on the knee extensor during the sprint, which may contribute to knee injury. The trunk flexor seems to be able to efficiently generate energy and absorb shock by preventing

TABLE 3. Correlation coefficients between WAnT and ITST variables.

Variables	PP (W)	MP (W)	FI (%)	PP (W/kg)	MP (W/kg)
TES - 30° (Nm)	0.629**	0.654**	0.271	0.457**	0.494**
TFS - 30° (Nm)	0.507**	0.559**	-0.141	0.267	0.337
TEP - 120° (Nm)	0.411*	0.468**	0.342	0.242	0.334
TFP - 120° (Nm)	0.555**	0.720**	-0.219	0.340	0.616**

*$P < 0.05$; **$P < 0.01$

PP, peak power; MP, mean power; FI, fatigue index; TES, trunk extension strength; TFS, trunk flexion strength; TEP, trunk extension power; TFP, trunk flexion power.

TABLE 4. Multiple regression analysis of predictors of the WAnT peak power (W).

Variables	Group N = 31			
	B	B	SE	*P*-value
Trunk extension strength - 30° (Nm)	1.262	0.586	0.260	0.000
Trunk flexion strength - 30° (Nm)	2.055	0.451	0.549	0.001
R^2= 59.7%; F = 13.997				

TABLE 5. Multiple regression analysis of predictors of the WAnT mean power (W) .

Variables	Group N = 31			
	B	β	SE	*P*-value
Trunk flexion power - 120° (Nm)	1.181	0.574	0.213	0.000
Trunk extension strength - 30° (Nm)	0.731	0.480	0.158	0.000
R^2= 72.7%; F = 21.519				

the upright posture of the trunk by continuously bowing the trunk forward. In fact, a trunk flexion angle greater than 7.2% contributed to energy efficiency by reducing the muscle strength and shock absorption in the knee joints to 13.3% and 23.3%, respectively, [28]. This explains the important role of the trunk flexors during anaerobic power. In particular, the trunk flexor power seems to have influenced the overall anaerobic power performance due to the type II fiber activation of the flexor and synchronization, such as muscle fiber recruitment ability and timing. Esbjörnsson *et al.* (1993) [29]. reported that anaerobic performance is mostly provided by type II fibers. Type II fibers are widely distributed in the global muscles and type I fibers are increasingly distributed in the local muscles [30].

In the trunk flexor, the global muscles are the rectus abdominis and the external abdominal muscles [31]. The rapid contraction of these muscles is suggested to maintain the flexion of the trunk continuously during strong anaerobic exercises. In addition, in order to achieve the trunk stability, the majority of the trunk muscles (local and global) must be operated in batch; additionally, proper muscle recruitment and timing are important [32]. While exerting anaerobic power, it is proposed that the power of the flexor makes an important contribution to the synchronization of muscle contraction. These results suggest that in order to improve the anaerobic power, flexion power training should be considered to strengthen the type II fibers of the trunk flexors and cause local and global muscle synchronization.

Trunk extensors are important muscles for maintaining posture [33]. These muscles help stabilize the spine with the ability to resist gravity in body posture and movement [34]. In particular, they enable effective deceleration of the forces generated in the anterior trunk muscles to provide the optimal position of the trunk [35]. In addition, strong trunk extensors can transfer energy without loss by immobilizing the upper body in arm swings during sprinting and in situations where forces generated on one side of the lower limb move to the other [36, 37]. It is suggested that the characteristics of the trunk extensor muscle strength are important during the anaerobic power exertion by providing an optimal position of the trunk and maintaining a stable posture. Therefore, the rapid contractility of the trunk flexor and the postural stabilization ability of the extensor seem to play important roles in supplying energy without oxygen. Considering these results, it is considered that core training should be conducted with a focus on improving the TFP and TES to exert strong anaerobic power (mean power).

5. Conclusions

This study confirmed the relationship of trunk muscle strength and anaerobic power which has not been reported in previous studies. These results suggest that trunk strength and power must be developed to improve the anaerobic capacity. However, there are some limitations to our study. First, we have not performed a clinical trial (intervention) whether core strength training has an effect on anaerobic power. Our study was a cross-sectional observational study. Second, as our study subjects were male soccer players from college, there is a limit to the generalization. In future studies, research is required to supplements these limitations.

Author contributions

All authors designed the data collection method, collected the data, analyzed the data and reviewed drafts of the paper. Hong-Sun Song, Buong-O Chun and Kihyuk Lee analyzed the data, wrote the paper, prepared tables and reviewed drafts of the paper. Hong-Sun Song and Kihyuk Lee analyzed the data, prepared tables and reviewed drafts of the paper. All authors read and approved the final manuscript.

Acknowledgements

This study was conducted with the support of the Korea Institute of Sport Science (Korea Sports Promotion Foundation). We thank all subjects for participating in this study.

Conflict of interest

The authors declare that they have no competing interests.

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