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Original Article

The comparison of bilateral strength of thigh muscles in long-distance runners with history of anterior knee pain

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Abstract

Thigh muscles imbalance leads to the increase of lower extremity injury in long-distance running. This study aimed to compare isokinetic parameter of bilateral strength imbalance in long distance runners with and without history of anterior knee pain. Forty-eight long distance runners; 26 males and 22 females were divided into two groups 1) with history of anterior knee pain and 2) no history of anterior knee pain. Knee flexors and extensors were assessed by Biodex isokinetic dynamometer at 3 angular velocities. The results showed that the quadriceps peak torque had significant differences at 60 $^{o}\cdot s^{-1}$ and 120 $^{o}\cdot s^{-1}$ between groups, p=0.007 and 0.038 respectively. The quadriceps total work at the speed of 120 $^{o}\cdot s^{-1}$ and 180 $^{o}\cdot s^{-1}$ demonstrated significant difference between two groups, p<0.001 and 0.044 respectively. This finding found the difference between the long-distance runners with and without the history of anterior knee pain, by which an appropriate intervention program to promote long-distance runners' performance should be emphasized in further studies.

Keywords: muscle performance, thigh muscles, imbalance, isokinetic, long distance runner, anterior knee pain

1. Introduction

Running recently became the most popular exercise around the world (Lee, Reid, Elliott & Lloyd, 2009). There are several health benefits from running such as improvement of cardiovascular, musculoskeletal and immune systems. In addition, running exercise can prevent cardiac diseases, hypertension and hyperlipidemia. (Lee *et al.*, 2009; Macera, Pate & Woods,1991). Nevertheless, inappropriate running biomechanics or lack of training performance in many long-distance runners can cause musculoskeletal injuries. (Barton, Bonanno, Carr, Neal, Malliaras & Franklyn-Miller, 2016)

In 2005, it was found that the incidence of injury among marathon runners ranged between 19.4 and 79.3% (Yamato, Saragiotto, Espanhol, Yeung & Lopes, 2015). Moreover, 84.9% of incidence of musculoskeletal injuries could limit running performance such as distance, speed and duration of training (Bovens *et al.*, 1989). Likewise, the percentage of musculoskeletal injury in marathon runners in Thailand was found around 31.2% occurring at knee, ankle and calf muscles (Upiriyasakul *et al.*, 2015). Anterior knee pain was one of the symptoms that mostly found in runners (Yamato *et al.*, 2015). Because of the fact that these runners were poor of physical fitness and inappropriate running biomechanics as well as the 90% of injured runners still have chronic musculoskeletal symptoms (Upiriyasakul *et al.*, 2015; Van Ginckel *et al.*, 2009; Witvrouw, Lysens, Bellemans, Cambier & Vanderstraeten, 2000). The side-to-side difference of the thigh muscle strength over 15% can increase the rate of knee and thigh injury on the weaker side (Ghani Zadeh Hesa *et al.*, 2009; Jacabs, Seeley, Sterling & Good-Rich, 2005). Due to, the anterior knee pain runners could not maintain their postural stability during running which can cause by the hamstring weakness. (Lee *et al.*, 2009) Similarly, the study of Knapik et al, presented that track and field players who had a high difference of thigh muscle strength between two sides also had higher injuries in lower extremities. (Knapik, Bauman, Jones, Harris & Vaughan, 1991; Yamamoto, 1993)

Several previous studies (Bennell *et al.*, 1998; Cheung, Smith & Wong, 2012; Cowley, Ford, Myer, Kernozek & Hewett, 2006) investigated side to side muscle imbalance in various kinds of sports but not in long-distance

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running. However, the electromyography of thigh muscles in long-distance runner is different from other sports, which might perhaps influence to the peak torque and total work of quadriceps and hamstrings muscles in other aspects.

Thus, the purpose of this study was to investigate the difference of peak torque and total work of quadriceps muscle in long-distance runners between with and without history of anterior knee pain. We hypothesized that the differences of bilateral strength and endurance of thigh muscles could be detected in long-distance runners with the history of anterior knee pain while it could not be observed in ones without the history of anterior knee pain.

2. Methods

2.1 Study design

Cross- sectional comparative study was designed and conducted at Physical Therapy Center, Faculty of Physical Therapy, Mahidol University. The ethical committee of Mahidol University, Central Institutional Review Board (MU-CIRB 2018/066.1403) proved this study protocol before the data collection.

2.2 Participants

Forty-nine long distance runners came for annual marathon assessment program in 2017 of Physical Therapy Clinic including knee muscles strength assessment and general examination gave consent before participation. The participants who presented pain on the day of testing would be excluded. There was an incomplete data from one participant. Sample size calculation was determined based on the results of our pilot study. The confidence interval was set at 95%, with alpha level 5%, power 80%, mean difference 12.0 and standard deviation 14.54 (peak torque of quadriceps and hamstring). Therefore, the data of 48 long distance runners were collected and analyzed.

A total 48 long distance runners consisted of 26 males and 22 females, aged 41.58 $\pm$ 8.06 years, BMI 23.83 $\pm$ 3.19 kg/m^2, body fat 25.36 $\pm$ 6.08 percent were divided into two groups 1) runners with the history of anterior knee pain (HAKP) in the last 6 months and 2) runners without the history of anterior knee pain (NAKP) according to history taking and physical examination screening was done by more than 5 years experienced physical therapists. Participants with history of pain at anterior knee while prolong walking, running and walking up-down the steps. (Sakunkaruna, Sakunkaruna & Sakulsriprasert, 2015)

2.3 Outcome measures

There were two outcome measures; 1) peak torque of quadriceps and hamstring. 2) Total works of quadriceps and hamstring. The Biodex isokinetic dynamometer (Biodex Multi-Joint system 4 Pro^{TM}, New York, USA) was used to assess the quadriceps and hamstring peak torque (CON /EXT, CON/ FLEX) and total work at three different angular velocities; 60 $^o{\cdot}s^{-1}$, 120 $^o{\cdot}s^{-1}$ and 180 $^o{\cdot}s^{-1}$. The measurement protocol was standardized by the machine program. The participants seated with their trunks and thighs stabilized with the straps. The tested leg was placed on the knee dynamometer which the knee joint was arranged at the axis of dynamometer. Before data collection, the weight of participant's leg was normalized by standardized isokinetic software.

The testing protocol was run by the standard program in software that all participants performed at the maximal contraction of knee extension and knee flexion in three different velocities (60 $^o{\cdot}s^-$, 120 $^o{\cdot}s^-$, 180 $^o{\cdot}s^-$). The maximal contraction was done in 5 repetitions of each speed and 1-minute rest between each trial provided. All subjects were asked to make an attempt at maximal strength and maximum velocity by vocal motivation. The deficit value of each outcome measurements were calculated by the program of the machine.

2.4 Statistical analysis

The Shapiro-Wilk test was used for data normality test in all variables. The data in this study were normally distributed. The comparisons between two groups (HAKP and NAKP) were investigated by independent t-test. The significant level was set at p-value <0.05. All statistical analysis was calculated by SPSS version 19.

3. Results

The characteristic data are shown in Table 1. Both groups were not significantly different in age, body mass index, and percent body fat between two groups**.** Table 2 showed side to side data in mean and standard deviation.

3.1 Peak torque

The result of this study (Table 3) showed that the speed 60 $^o{\cdot}s^{-1}$had a significant difference of quadriceps peak torque deficit in HAKP group representing quadriceps peak torque deficit (9.86±16.93) rather than NAKP group (2.72±12.61) with p=0.007. Likewise, at speed 120 $^o{\cdot}s^{-1}$the HAKP group had a quadriceps peak torque deficit (7.09±18.56) rather than NAKP group (1.92±10.52) with p=0.038. There were no significant different of hamstring peak torque deficit.

3.2 Total work

There were significant differences of quadriceps total work deficits at speed 120 and 180 $^o{\cdot}s^{-1}$, by which 120 $^o{\cdot}s^{-1}$, the HAKP group had quadriceps total work deficit (15.02±17.43) rather than NAKP group (2.83±13.73) with p<0.001 and 180 degrees per second, quadriceps total work deficit in the HAKP group (10.04±16.30) greater than NAKP group (0.58±16.12) with p=0.044. There were no significant different of hamstring total work deficits.

4. Discussion

This study aimed to compare the deficits of peak torque and total work in quadriceps and hamstring muscles using isokinetic dynamometer in long-distance runners with and without the history of anterior knee pain. The results of this study showed the deficit in quadriceps muscle both peak torque and total work in long-distance runners who had the

Table 1. Characteristic data of the participants

	Group	N	Mean + SD	Sig. (2-tailed)
Age (YEARS)	No Anterior knee pain (NAKP)	34	40.59 ± 7.57	0.149
	History Anterior knee pain (HAKP)	14	44.21 ± 8.89	
BMI (KG/m^2)	No Anterior knee pain (NAKP)	34	24.05 ± 3.39	0.465
	History Anterior knee pain (HAKP)	14	23.30 ± 2.65	
Percentage of body fat	No Anterior knee pain (NAKP)	34	25.40 ± 6.67	0.948
	History Anterior knee pain (HAKP)	14	25.27 ± 4.57	

Table 2. Side to side data in mean and standard deviation

	No Anterior knee pain (NAKP)		History Anterior knee pain (HAKP)	
	Uninvolve side	Involve side	Uninvolve side	Involve side
60 degree per Sec.				
Quadriceps peak torque	103.69±31	105.57±27	108.18±40	95.56±35
Hamstring peak torque	47.57±17	47.81±17	49.65±23	46.12±21
Quadriceps total work	297.97±93	291.82±91	282.65±72	263.27±79
Hamstring total work	151.42±69	148.04±58	151.93±50	138.9±71
120 degree per Sec.				
Quadriceps peak torque	87.81±24	89±24	85.90±32	75.96±21
Hamstring peak torque	42.89±16	42.7±15.31	42.38±16	41.5±16
Quadriceps total work	270.08±83	274.90±84	265.70±73	224.25±72
Hamstring total work	143.42±62	143.88±60	145.90±47	132.12±57
180 degree per Sec.				
Quadriceps peak torque	73.87±23	73.85±20	70.76±26	64.09±19
Hamstring peak torque	36.47±16	36.16±16	35.12±13	35.67±14
Quadriceps total work	239.03±81	237.19±75	235.40±78	205.65±58
Hamstring total work	118.94±64	122.52±64	118.98±42	110.33±48

Table 3. The deficit of peak torque and total work of quadriceps and hamstring muscles

	No Anterior knee pain (NAKP)	History Anterior knee pain (HAKP)	*p*-value
60 degree per Sec.			
Quadriceps peak torque	2.72+12.61	9.86 ± 16.93	0.007*
Hamstring peak torque	4.40+29.33	5.76 ± 22.83	0.253
Quadriceps total work	0.33+24.86	6.10 ± 20.97	0.450
Hamstring total work	8.46+49.13	9.90 ± 37.78	0.217
120 degree per Sec.			
Quadriceps peak torque	1.92+10.52	7.09 ± 18.56	0.038*
Hamstring peak torque	2.56+21.87	1.73 ± 25.15	0.556
Quadriceps total work	2.83+13.73	15.02 ± 17.43	< 0.001*
Hamstring total work	5.08+30.89	10.02 ± 29.77	0.127
180 degree per Sec.			
Quadriceps peak torque	1.39+14.72	6.59 ± 15.31	0.098
Hamstring peak torque	3.35+26.43	2.64 ± 30.64	0.936
Quadriceps total work	0.58+16.12	10.04 ± 16.30	0.044*
Hamstring total work	14.49+55.1	7.12 ± 32.65	0.178

history of anterior knee pain. However, no significant difference between groups in hamstring peak torque and total work deficits in three angular velocities was found.

4.1 Peak torque

The side-to-side differences representing the deficit were found in many functions in sport activities (Newton *et al.*, 2006). Especially, in lower extremities imbalance, it was determined in the study of Newton Ru (Newton *et al.*, 2006), by which the differences between dominant and non-dominant sides were found from 4.2% to 16.0% in sport activities.

The lower body strength deficit was related in high risk factor of lower extremity injury. The previous studies (Callaghan & Baltzopoulos, 1994; Clanton & Coupe, 1998; Thijs, De Clercq, Roosen & Witvrouw, 2008; Witvrouw *et al.*, 2000) showed high risk for lower extremity injury in several kind of sports. The risk factor for anterior cruciate ligament injury in female basketball and football athletes were found in side-to-side strength imbalance group (Cowley *et al.*, 2006).

As the result of this study, it was found in long-distance runners with the history of anterior knee pain in quadriceps peak torque deficits between 7.09% and 9.86%. However, side-to-side hamstring peak torque and total work deficits showed no significant difference between two groups in the present study. On the other hand, the previous studies by Orchard *et al.* (Bennell *et al.*, 1998; Orchard, Marsden, Load & Garlick, 1997) reported hamstring muscle weakness associated with hamstring injury by side-to-side peak torque ratio at low velocity. Moreover, several studies (Ardern, Pizzari, Wollin & Webster, 2015) showed that the imbalance of thigh muscles strength in football players can lead to 4.6 times to increase risk in hamstring injury.

4.2 Total work

For long distance runners, this study was found the trends that a total work deficit seemed to be at the higher velocities, 120 $^{o}\cdot s^{-1}$ and 180 $^{o}\cdot s^{-1}$. Due to the previous study (Dellagrana *et al.*, 2015), the high angular velocity during running was presented between 400 $^{o}\cdot s^{-1}$ to 600 $^{o}\cdot s^{-1}$. Therefore, the result of our study showed the significant difference of total work in high velocity not the low velocity. Similarly, the several studies (Dellagrana, Diefenthaeler, Carpes, Hernandez & Campos, 2015; Orchard *et al.*, 1997) investigated extremities asymmetry showed the significant difference of peak torque of knee flexion and extension in the high angular velocity in injured long-distance runners. In addition, the hamstring peak torque difference was found at higher velocity in healthy individuals at 300 $^{o}\cdot s^{-1}$ and 180 $^{o}\cdot s^{-1}$ rather than $60^{o}\cdot s^{-1}$ (Kobayashi *et al.*, 2013; Kong & Burns, 2010). This reduction in higher angular velocity reflected the challenge of the tested muscles regarding their force production in higher angular velocity since the explosion of force production is challenged with the increased demand of neuromuscular and energy expenditure controls. In contrast, the unexpected result of the study of Lee MJ (Lee *et al.*, 2009) showed that the quadriceps total work of injured sprinting runners was significantly more than the uninjured runner group. Thus, this finding might be discussed by the overloaded of quadriceps muscles on the injured sprinting runners. However, our study focused only on muscle performance in long-distance runners.

4.3 Limitations of the study

The experiences of long-distance running and the duration of anterior knee pain might affect the results of the peak torque and total work of quadriceps and hamstring muscles among long-distance runners. Therefore, the future study should characterize those long-distance runners in subgroups according to their experiences or the duration of anterior knee pain for making better comprehension in the mechanisms of anterior knee pain which will add to the history taking form and could perhaps find the appropriate rehabilitation program in the future. In addition, for further study the researchers consider a prospective study to investigate the prevalence of anterior knee pain in this population.

5. Conclusions

The study found the significant difference of bilateral strength of quadriceps femoris muscles in long distance runners with history of anterior knee pain.

References

Ardern, C. L., Pizzari, T., Wollin, M. R., & Webster, K. E. (2015). Hamstrings strength imbalance in professional football (soccer) players in Australia. *Journal of Strength and Conditioning Research*, *29*(4), 997–1002. doi:10.1519/JSC.00000 00000000747

Barton, C. J., Bonanno, D. R., Carr, J., Neal, B.S., Malliaras, P., & Franklyn-Miller, A. (2016). Running retaining to treat limb injuries: a mixed-methods study of current evidence synthesized with expert opinion. *Journal of Sports Medicine*, *50*, 1-16. doi:10.1136/ bjsports-2015-095278

Bennell, K., Wajswelner, H., Lew, P., Schall-Riaucour, A., Leslie, S., Plant, D., & Cirone, J. (1998). Isokinetic strength testing does not predict hamstring injury in Australian rules footballers. *British Journal of Sports Medicine*, *32*, 309-314. doi:10.1136/bjsm. 32.4.309

Bovens, A. M., Janssen, G. M., Vermeer, H. G., Hoeberigs, J. H., Janssen, M. P., & Verstappen, F. T. (1989). Occurrence of running injuries in adults following a supervised training program. *International Journal of Sports Medicine*, *10*(Supplement 3), S186-S190. doi:10.1055/s-2007-1024970

Callaghan, M. J. & Baltzopoulos, V. (1994). Gait analysis in patients with anterior knee pain. *Clinical Biomechanics*, 9, 79-84. doi:10.1016/0268-0033 (94)90028-0

Cheung, R. T. H., Smith, A. W., & Wong, D. P. (2012). H:Q ratio and bilateral leg strength in college field and court sport players. *Journal of Human Kinetics*, *33*, 63-71. doi:10.2478/v10078-012-0045-1

Clanton, T. O. & Coupe, K. J. (1998). Hamstring strain in athletes: Diagnosis and treatment. *Journal of American Academy of Orthopedic Surgeons*, *6*, 237-248. doi:10.5435/00124635-199807000-00005

Cowley, H. R., Ford, K. R., Myer, G. D., Kernozek, T. W., & Hewett, T. E. (2006). Differences in neuromuscular strategies between landing and cutting task in female basketball and soccer athlete. *Journal of Athletic Training*, *41*, 67-73.

Dellagrana, R. A., Diefenthaeler, F., Carpes, F. P., Hernandez, S. G., & Campos, W. (2015). Evidence for isokinetic knee torque asymmetries in male long distance-trained runners. *International Journal of Sports Physical Therapy*, *10*(4), 514-519.

Ghani Zadeh Hesar, N., Van Ginkel, A., Cools, A., Peersman, W., Roosen, P., De Clercq, D., & Witvrouw, E. (2009). A prospective study on gait-related intrinsic risk factor for lower leg overuse injuries. *British Journal of Sport Medicine*, *43*, 1057-1061. doi:10.1186/s13047-014-0053-6

Jacobs, C. T., Seeley, U. M., Sterling, W., & Good-Rich, L. (2005). Strength and fatigability of the dominant and nondominant hip abductors. *Journal of Athletic Training*, *40*, 203–206.

Knapik, J. J., Bauman, C. L., Jones, B. H., Harris, J. M., & Vaughan, L. (1991). Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *The American Journal of Sports Medicine*, *19*, 76-81. doi:10.1177/036354659101900113

Kobayashi, Y., Kubo, J., Matsubayashi, T., Matsuo, A., Kobayashi, K., & Ishii, N. (2013). Relationship between bilateral differences in single leg jumps and asymmetry in isokinetic knee strength. *Journal of Applied Biomechanics*, *29*, 61–7. doi:10.1123/jab.29.1.61

Kong, P. W., & Burns, S. F. (2010). Bilateral difference in hamstrings to quadriceps ratio in healthy males and females. *Physical Therapy in Sports Journal*, *11*, 12–7. doi:10.1016/j.ptsp.2009.09.004.

Lee, M. J., Reid, S. L., Elliott, B. C., & Lloyd, D. G. (2009). Running biomechanics and lower limb strength associated with prior hamstring injury. *Medicine and Science in Sports and Exercise*, *41*(10), 1942–1951. doi:10.1249/MSS.0b013e3181a55200.

Macera, C. A., Pate, R. R., & Woods, J. R. (1991). Post-race morbidity among runners. *American Journal of Preventive Medicine*, *7*, 194-198.

Newton, R. U., Gerber, A., Nimphius, S., Shim, J. K., Doan, B. K., Robertson, M., . . . Kraemer, W. J. (2006). Determination of functional strength imbalance of the lower extremities. *The Journal of Strength and Conditioning Research*, *20*(4), 971-977. doi:10.1519/R-5050501x.1

Orchard, J., Marsden, J., Load, S., & Garlick, D. (1997). Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *The American Journal of Sports Medicine*, *25*, 81-85. doi:10.1177/036354659702500116

Sakunkaruna, S., Sakunkaruna, Y., & Sakulsriprasert, P. (2015). Thai version of the Kujala patellofemoral questionnaire in knee pain patients: cross-cultural validation and test-retest reliability. *Journal of The Medical Association of Thailand*, *98*(Supplement), 1-7.

Thijs, Y., De Clercq, D., Roosen, P., & Witvrouw, E. (2008). Gait-related intrinsic risk factors for patellofemoral pain in novice recreational runners. *British Journal of Sport Medicine*, *42*, 466-471. doi:10.1136/bjsm.2008.046649.

Upiriyasakul, R., Bovonsunthonchai, S., Sakunkaruna, Y., Sakunkaruna, S., Thong-on, S., & Laisirirungrai, D. (2015). Incidence of injuries in marathon runners; Bangkok marathon. *Journal of Sports Science and Medicine*, *15*(1), 171-178.

Van Ginckel, A., Thijs, Y., Zadeh Hesar, NG., Mahiru, N., De Clercq, D., Roosen, P., & Witvrouw, E. (2009). Intrinsic gait-related risk factors for Achilles tendinopathy in novice runners: A prospective study. *Gait Posture*, *29*, 387-391. doi:10.1016/j.gaitpost.2008.10.058

Witvrouw, E., Lysens, R., Bellemans, J., Cambier, D., & Vanderstraeten, G. (2000). Intrinsic risk factors for the development of anterior knee pain in an athletic population: a two-year prospective study. *The American Journal of Sports Medicine*, *28*, 480-489. doi:10.1177/03635465000280040701

Yamamoto, T. (1993). Relationship between hamstring strains and leg muscle strength: a follow-up study of collegiate track and field athletes. *The Journal of Sports Medicine and Physical Fitness*, *33*, 194–199.

Yamato, T. P., Saragiotto, B. T., Hespanhol Junior, L. C., Yeung, S. S., & Lopes, A. D. (2015). Descriptors used to define running-related musculoskeletal injury: A systematic review. *Journal of Orthopaedic and Sports Physical Therapy*, *45*(5), 366-374. doi:10.2519/jospt.2015.575