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Effects of a hip-core warm-up protocol on Q-angle during single-leg drop jump in 18–35 years old healthy female runners

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KEYWORDS
Q-angle;
Warm-up;
Single leg drop jump;
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ABSTRACT
Changing of Q-angle could detect abnormal biomechanics while running especially lower extremity. Increasing the angle can cause knee pain in various runners. Weakness and fatigue of hip-core muscles during exercises are the main factors that alter the angle and contribute to knee pain. Maintaining muscle performance through the running race and improving their strength are beneficial to athletic performance and decrease the injury rate. Unfortunately, there is no evidence of effectiveness of hip–core warm-up affects the Q-angle. The study aimed to investigate the effects of a hip–core warm-up protocol on the Q-angle during single-leg drop jump in 18–35 years old healthy female runners. Twenty-eight healthy female runners at the age of 18–35 participated and were randomly assigned to the exercise and control groups, fourteen in each. All runners performed pre-warm-up, post-warm-up and post-exercise single-leg drop jump test and the Q-angle was recorded by video cameras. The exercise group was assigned to have the hip–core warm-up protocol and the warm-up protocol for runners, while the control group was assigned to have only the warm-up protocol for runners. The results were compared within testing conditions and between two groups. In the exercise group, the result demonstrated that the Q-angle after warm-up programs was significantly decreased and was slightly increased after the 30-minute treadmill running. In the control group, this angle did not show any change. However, after 30-minute treadmill running, the angle showed a considerable increase and reached more than both pre-warm-up and post-warm-up angles. When compared between groups, the Q-angle was not altered significantly in any comparable. In conclusion, the hip-core warm-up protocol could immediately decrease the Q-angle and maintain the angle though 30-minute running. In contrast, the warm-up routine program could not decrease the angle, and it was higher than pre-warm up after finishing treadmill running. So, professionals should advise the hip-core warm-up protocol to reduce the risk of knee injuries in the runner

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Introduction

The patellofemoral angle (Q-angle) represents the vector of pull exerted by the quadriceps muscles on the patella[1-2]. Ten percent increasing the angle during the single-leg landing phase could rise lateral tracking force on the patella and 45% increased compression force on the patella-femoral joint[3]. Abnormal forces could cause patellofemoral pain syndrome (PFPS), found in runners at a 25% prevalence rate[1-2]. Single-leg landing is an important mechanism which continuously impacts a patellofemoral joint force during running. The Q-angle measurement can detect weakness and fatigue of hip-core muscles that play an essential role in controlling runners' movement[4]. Paz AG et al. 2018[5] found that the Q-angle increased significantly during single-leg landing and was related with proper hip–core muscle activation.

The previous study found that the Q-angle changed by 0.216° when these muscles were 1% stronger[6]. In 2015[7], two rehabilitation programs were compared to increase the muscles' strength around the hip-core and the muscles around the knee joint in PFPS for six weeks. The results showed that both programs could reduce pain and increase muscle strength, but the hip joint-core exercises provided faster results and increased overall muscle strength. Nevertheless, some studies show proper warm-up programs before exercise, stimulating muscle readiness and increasing physical fitness by 79% and reducing the injury rate. Besides, they can stimulate a motor unit recruitment that allows the muscles to work more efficiently[8]. So, the hip–core warm-up protocol might immediately stimulate those muscles to control runners' movements and last long until they finish exercises to decrease the risk of knee injuries. However, there was no evidence to support the hypothesis. This study's objective was to study the effects of a hip–core warm-up protocol on Q-angle during single-leg drop jump in healthy female runners at the age of 18 - 35 years.

Materials and methods

Participants

The pilot study results were used to calculate the sample size by G-power program, which was twenty-eight total. Healthy female runners with a normal BMI and 18 - 35 years and practised at least 32 - 40 km per week participated in this study. Volunteers were randomly assigned to two groups, with 14 participants in each group.

The exercise group followed a hip–core warm-up protocol and warm-up routine for runners, while the control group performed only a warm-up routine for runners. None of the participants felt pain or any discomfort of the lower extremities or had a history of leg or back operation. In the three days before the study, participants were asked to abstain from treatments, including massage and anti-inflammatory drugs (NSAID). The Ethic Review Sub-Committee Board for Human Research Involving Sciences, Thammasat University, No. 3 (ECScTU) approved this study (approval number 076/2562).

Protocol

The volunteers who had met the inclusion and exclusion criteria participated in three vertical drop jump tests comprising pre-warm up, post-warm up and post-exercise jump test. Before the tests, reflexive markers were attached to the subjects to locate six bony prominences in the testing leg: anterior superior iliac spine (ASIS), mid-point of the patella, tibial tubercle, greater trochanter, lateral epicondyle of the femur, and lateral malleolus. The researcher (A), who was blinded to the participants' condition, also placed two video cameras, 50 cm. high, 3 m. away from a wooden box with a height of 30 cm. The first camera took pictures in the frontal plane, and the second camera took pictures in a sagittal plane. Volunteers stood on the wooden box with both hands on the waist. The volunteer extended the test leg (dominant leg) forward. Then, the volunteer jumped onto the ground with one leg and was able to stand on the test side. Three jump tests were performed with 30 seconds rest between the jumps.

Warm-up protocols

Volunteers received a warm-up program according to groups under supervision by the researcher (B). The exercise group received the hip-core warm-up protocol as shown in Table 1 in conjunction with the warm-up routine for runners as shown in Table 2, which took approximately 15 minutes while the control group received only a warm-up program. The hip-core warm-up protocol contains ten warm-up poses, according to Costa PB. in 2011[9]. The warm-up routine for the runner features seven warm-up moves, according to Runner world magazine in 2014[10].

Table 1 The hip-core warm-up protocol[9]

Exercises	Intensity
Lunges with unilateral trunk rotation	8 rep / set 3 sets
Lunges with unilateral trunk rotation	10 sec / set 3 sets
Elbow extension (sprawl)	10 rep / set 3 sets
Superman	10 rep / set 1 set
Static crunches with hip abduction (2 sides)	10 sec / set 3 sets
Static crunches with the hip flexed and trunk rotation (2 sides)	10 rep / set 1 set
Static crunches with trunk rotation lying down (2 sides)	10 rep / set 3 sets
Static crunches with rotation standing up (2 sides)	10 rep / set 1 set
Static elbow extension with unilateral knee flexion (2 sides)	10 rep / set 3 sets
Standing from the guard (2 sides)	10 rep / set 1 set

Table 2 The warm-up routine for the runner[10]

Exercises	Intensity
Active hamstring stretches	10 rep / set 3 sets
Walking straight leg kick up	10 rep / set 3 sets
Walking quad stretch	10 sec / set 3 sets
Walking leg cradle	10 rep / set 3 sets
Walking in-step stretch	10 rep / set 3 sets
Walking single leg RDL	10 rep / set 3 sets
Walking inchworm	10 rep / set 3 sets

Exercise program

Volunteers ran on a treadmill according to the researcher defined program for 30 minutes with the researcher adjusting the speed and timing for each interval.

Data processing

The recorded data were imported into the Kinovea motion analysis program (Kinovea.org, version 0.9.3) to measure maximal knee flexion during landing phase in the sagittal plane. The Q-angle was measured at the peak knee flexion angle. The mean value obtained from three jumps was used for statistical analysis.

Statistical analysis

Fragmentation of the data was analysed in SPSS version 24 by using the Shapiro-Wilk normality test. Comparison of the Q-angle while jumping with one leg before and immediately after warming up and after running on the treadmill within the groups and comparing the groups was done using two-way ANOVA and the least significant difference (LSD) test. This study

defined the degree of statistical significance at *p*-value < 0.05.

Results

The general participant characteristics included average age, weight, height and body mass index (Table 3) were statistically not significantly different between exercise group (n = 14) and control group (n = 14).

Table 3 General participant characteristics

Characteristics	Exercise group (Mean ± SD)	Control group (Mean ± SD)
Age (year)	21.07 ± 1.14	21.71 ± 0.91
Weight (kg)	52.71 ± 4.30	52.48 ± 4.96
Height (cm)	159.64 ± 3.81	161.11 ± 6.78
BMI (kg/m^2)	20.71 ± 1.80	20.20 ± 2.08

Figure 1 demonstrates the difference of Q-angle between each single-leg drop jump test in the exercise and the control groups. The exercise group showed a significant decrease after performing the warm-up protocol (16.43 ± 3.61˚) with *p*-value of 0.028 and slightly increased after the 30-minute treadmill running. The post-running Q-angle (17.5 ± 4.20˚) remained lower than before performing the warm-up program (18.29 ± 3.75˚). Besides, warming up programs in this group could decrease the angle immediately and throughout the 30-minute treadmill running. Additionally, the control group was not different when compared between the pre-warm-up (17.36 ± 8.53˚) and post-warm-up angle (17.00 ± 7.66˚). However, after 30-minute treadmill running, the angle showed a considerable increase (18.71 ± 8.14˚) (*p*-value 0.041) and reached more than both pre-warm-up and post-warm-up angles.

Figure 2 demonstrates a comparison of Q-angle differences between exercise and control groups in each single-leg drop jump test. The analysis found no significant difference in the angle between groups. However, even pre-warm up angle in the exercise group showed higher than the other. However, after warm-up, the angle was lower in both immediately post warm-up and after treadmill running.

Discussion

The study investigated the hip-core warm-up protocol on Q-angle during single-leg drop jump in twenty-eight, 18 - 35 years old healthy female runners. Participants were randomly assigned to the exercise and control group and performed three single-leg drop jump test, including pre-warm up, post-warm up, and post-exercise.

The main results demonstrated that the hip-core warm-up protocol could significantly decrease the angle and control it until finishing 30-minute treadmill running. Changing of the Q-angle resulted from the effectiveness of the hip-core muscles. The ability to control the hip and knee joint, associated with Q-angle changing, was related to the core muscles and the muscles surrounding the hip joint [4, 6]. Those were classified as stabiliser muscles[11, 12]. Studies have shown that a muscle-stimulating warm-up program can help muscles to work more efficiently [7, 15]. Stickler et al. in 2014[5] found that the hip and core muscles affected Q-angle when performing a single-leg squat. Also, when these muscles had been appropriately activated, it could decrease the Q-angle. A decline in the angle can lead to less compressive force on the patellofemoral joint[3]. So, it would help to decrease the risk of knee injuries caused by PFPS. Besides, after the

30-minute treadmill running, this group's angle showed slightly increased but remained lower than before performing the warm-up program. The increase could be the result of hip-core muscles fatigue that used to control movement. Studies have shown that 30-minutes running exercise can reduce muscle efficiency[13, 14]. Nevertheless, adding the hip-core protocol to regular warm-up programs could maintain the Q-angle for 30 minutes after running on the treadmill.

On the contrary, only the warm-up routine for runner protocol performed in the control group could not instantly decrease the angle. It was significantly higher after treadmill running. This warm-up program focused on lower limb muscle flexibility and functional activation, which targets prime movers muscles function during running[9]. According to specific muscle exercises, effective stimulation or strengthening of muscles was required to use a position that stimulates them directly[16]. Besides, the programs did not focus on hip-core stabiliser muscles which show directly affect the Q-angle. So, only the warm-up routine for runner protocol may not be enough to decrease the angle before exercise. After 30 - minute treadmill running, this group's angle showed higher than both pre and post-warm up due to failure of stabiliser muscles to control body mechanics during running, which caused by muscle fatigue[13, 14]. Thus, runners who prepare themselves by the warm-up routine for runner protocol only may impact the patellofemoral joint force more than combining with the hip-core warm-up protocol. In 2015, Stickler et al.[6] found that the Q-angle of hip and core muscle strengthening programs was not a statistically significant difference from the knee muscle strengthening programs in subjects with anterior knee pain. However, the hip-core exercise group was more likely to reduce the Q-angle and improve anterior knee pain.

The results suggested that the hip–core warm-up protocol that targets stabiliser muscle can reduce the Q-angle immediately and maintain through 30-minute treadmill running. Thus, therapists should advise this program to patients or athletes to reduce knee injury risk while running. Before applying for the program, athletes should be trained to follow the program properly to make their warm-up more effective. However, the study collected biomechanic data via two 2D cameras, which could not analyse the whole-body movement. Besides, gender difference may affect the results due to all participants were female. So, it would be a limitation. In further studies, due to humans' complex movement, the 3D motion analysis system would be further covered. Moreover, ground reaction force and foot pressure distribution may expand many points of view.

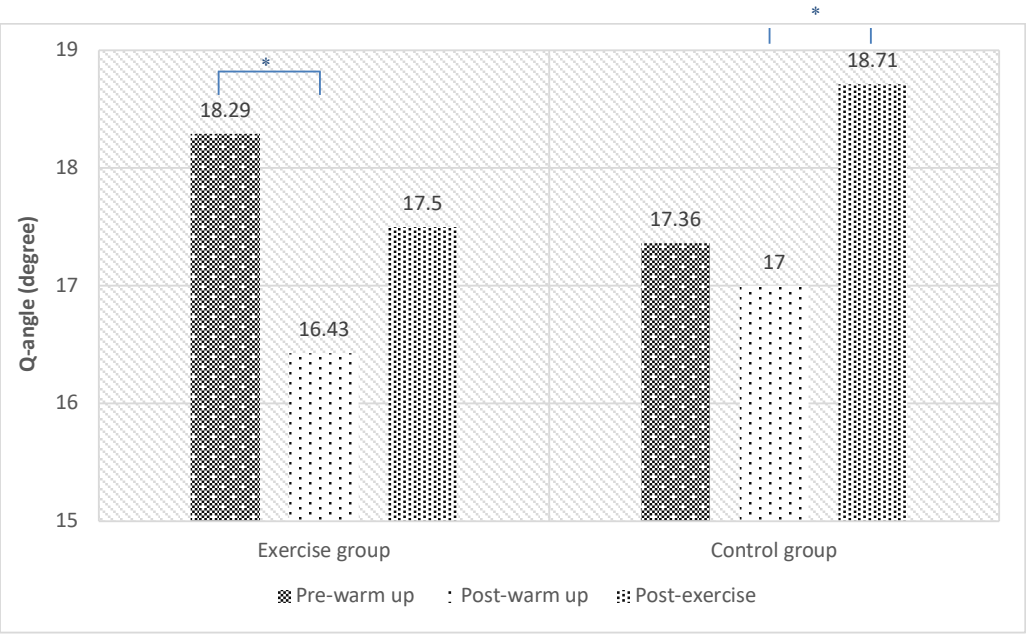

Figure 1 Q-angle differences between single-leg drop jump tests of the two groups
Note: *Significant level at *p*-value < 0.05

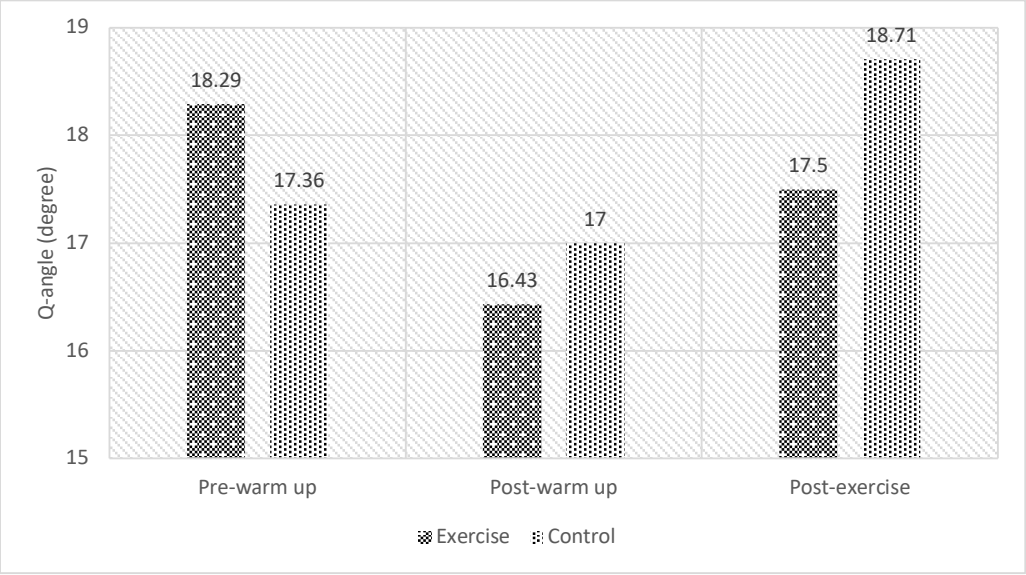

Figure 2 Q-angle between the exercise and control groups in each single-leg drop jump test.

Conclusion

The hip-core warm-up protocol could immediately decrease the Q-angle and could maintain the angle though 30 minutes running. In contrast, the warm-up routine program could not decrease the angle, and it was higher than pre-warm up after finishing treadmill running.

Take home messages

The hip-core warm-up protocol significantly reduced the Q-angle during single-leg drop jumps and could maintain the beneficial effect though 30-minute treadmill running.

Conflicts of interest

The authors declare no conflict of interest.

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References

1. Cook C, Mabry L, Reiman MP, Hegedus EJ. Best tests/clinical findings for screening and diagnosis of patellofemoral pain syndrome: a systematic review. J Physiother 2012; 98(2): 93-100.
2. Roush JR, Curtis Bay R. Prevalence of anterior knee pain in 18-35-year-old females. Int J Sports Phys Ther 2012; 7(4): 396-401.
3. Huberti HH, Hayes WC. Patellofemoral contact pressures. The influence of q-angle and tendofemoral contact. J Bone Joint Surg Am 1984; 66(5): 715-24.
4. Hollman JH, Ginos BE, Kozuchowski J, Vaughn AS, Krause DA, Youdas JW. Relationships between knee valgus, hip-muscle strength, and hip-muscle recruitment during a single-limb step-down. J Sport Rehabil 2009; 18(1): 104-17.
5. Paz GA, de Freitas Maia M, Santana HG, Miranda H, Lima V, Willson JD. knee frontal plane projection angle: a comparison study between drop vertical jump and step-down tests with young volleyball athletes. J Sport Rehabil 2019; 28(2): 153-8.
6. Stickler L, Finley M, Gulgin H. Relationship between hip and core strength and frontal plane alignment during a single leg squat. Phys Ther Sport 2015; 16(1): 66-71.
7. Ferber R, Bolgla L, Earl-Boehm JE, Emery C, Hamstra-Wright K. Strengthening of the hip and core versus knee muscles to treat patellofemoral pain: a multicenter randomized controlled trial. J Athl Train 2015; 50(4): 366-77.
8. Fradkin AJ, Zazryn TR, Smoliga JM. Effects of warming-up on physical performance: a systematic review with meta-analysis. J Strength Cond Res 2010; 24(1):140-8.
9. Costa PB, Medeiros HBO, Fukuda DH. Warm-up, stretching, and cool-down strategies for combat sports. Strength Cond J 2011; 33(6): 71-9.
10. Rice A. Top five marathon warm-up races. Runner's World. 2014.
11. Saez Saez de Villarreal E, Gonzalez-Badillo JJ, Izquierdo M. Optimal warm-up stimuli of muscle activation to enhance short and long-term acute jumping performance. Eur J Appl Physiol 2007; 100(4): 393-401.
12. Skof B, Strojnik V. The effect of two warm-up protocols on some biomechanical parameters of the neuromuscular system of middle-distance runners. J Strength Cond Res 2007; 21(2): 394-9.
13. Dierks TA, Manal KT, Hamill J, Davis IS. Proximal and distal influences on hip and knee kinematics in runners with patellofemoral pain during a prolonged run. J Orthop Sports Phys Ther 2008; 38(8): 448-56.
14. Kellis E, Liassou C. The effect of selective muscle fatigue on sagittal lower limb kinematics and muscle activity during level running. J Orthop Sports Phys Ther 2009; 39(3): 210-20.
15. Gorassini M, Yang JF, Siu M, Bennett DJ. Intrinsic activation of human motoneurons: reduction of motor unit recruitment thresholds by repeated contractions. J Neurophysiol 2002; 87(4): 1859-66.
16. Lin CY, Tsai LC, Press J, Ren Y, Chung SG, Zhang LQ. Lower-limb muscle-activation patterns during off-axis elliptical compared with conventional gluteal-muscle-strengthening exercises. J Sport Rehabil 2016; 25(2): 164-72.