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Original Article

Comparison of the Immediate Effects of Modified and Routine Warm-Ups on Knee Joint Function and Dynamic Balance in Athletes

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ABSTRACT

Background: Warm-up before a sport activity is the most common preventive measure to reduce the incidences and severity of injuries during sport activities. This study investigated the effects of modified warm-up on balance and knee function as compared to those of routine warm-up in athletes.
Methods: Twenty healthy athletes volunteered to participate in the study. At the beginning of the session, we evaluated the dynamic balance and the knee joint function variables by Star Excursion Balance Test (SEBT) and hop tests, and then the subjects did either modified or routine warm-up. Immediately after doing the warm-up, the dynamic balance and the knee joint function variables were assessed again. Each subject underwent both interventions in two sessions separated by at least 48 hours.
Results: Statistically significant improvements were measured for modified warm-up compared to routine warm-up in eight directions of SEBT and four hop tests. (A: P=0.0001, AL: P=0.005, L: P=0.002, PL: P=0.005, P: P=0.005, PM: P=0.0001, M: P=0.001, AM: P=0.001) (One-leg hop test for distance: P=0.007, triple hop test for distance: P=0.003, triple crossover hop for distance: P=0.004, and 6 meter timed hop test: P=0.0001).
Conclusion: Modified warm-up showed greater impact on improving dynamic balance and some indicators of knee joint function in athletes, and it thereby provides more appropriate conditions for physical activity and reduces incidences of sport injuries.

Introduction

Sport injury is a general term for all types of injuries that are related to physical sport activities [1]. Joint position sense (JPS) is a component of proprioception that plays an important role in maintaining dynamic stability of the joint, especially in the lower limb, and so its disturbance can be considered as a risk factor for lower limb injuries [2]. Knee instability, probably due to the decreased neuromuscular strength and coordination or increased ligamentous laxity, may underlie the increased incidences of knee injuries in sports. Warm-up exercises that affect knee JPS and knee function can improve knee joint stability and decrease the risk of sport injuries.

Balance is important for athletes because it not only improves athletic performance, but also plays an important role in preventing injuries. Therefore it is necessary to know how physical activities affect balance [3].

Balance is the ability to keep the center of gravity at the base of support with minimal movement and also the ability to perform a task while maintaining a stable position [4]. Therefore it is necessary to know how

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physical activities affect balance and neuromuscular control in order to reduce sport injuries.

Preventive measures can control the risk of injury and reduce the incidences and severity of injuries. Warm-up is a preventive measure for sport injuries. Several studies have examined the effects of a routine warm-up, including running and stretching, on proprioception and balance [5-7]. Magalhaes et al. showed that routine warm-up improved knee joint position sense in closed chain [7]. Salgado et al. also concluded that joint position sense increased after a 25-minute warm-up before competition [5]. Kanghoon et al. showed that warm-up exercises like stretching, treadmill and plyometric did not affect dynamic balance in healthy subjects [8]. To our knowledge, there has been no research to investigate the effects of modified warm-up, in the form of this study, on knee joint function and balance in athletes. The modified warm-up program has several components, including dynamic stretching rather than static stretching that was used in routine warm-up. According to some researches, static stretching has no advantage for improving performance and injury prevention [9-11]. Strengthening exercises were added to the modified warm-up, because stronger muscles around the joint can provide better balance and perform more efficient and explosive movements for a longer period of time. Following some powerful contractions, neuromuscular activity improved due to the increase in H-reflex amplitude, and so reduced the risk of injury. This effect remains 10 minutes after a contraction, leading to faster response in unstable situations[12]. Also, plyometric and agility activities are important parts of modified warm-up [10]. Plyometric is a type of resistance training that can improve balance, coordination, agility and power [8].

Different exercises with different purposes were used in two warm-up protocols. These exercises theoretically have different effects on neuromuscular mechanisms. The physiological and neuromuscular effects of the two protocols on knee performance and balance can vary in detail. The aim of this study was to evaluate the differences between the two protocols on knee joint function and balance in athletes in order to evaluate if modified warm-up could immediately improve balance and knee function more than routine warm-up, and possibly lead to greater prevention of future injuries in the lower extremity in athletes.

Methods

Subjects and Design

Twenty healthy subjects (12 females and 8 males) aged 19-24 years old with a mean age of 21.65±1.75 and mean height of 167.80±11.03cm, doing regular exercise at least three times a week for 45 minutes duration each time in the past year among different physical sport activities in the form of jumping, running, and fast-moving shifting such as basketball, soccer, and volleyball, volunteered for the study by convenient sampling. We excluded subjects with history of lower limb and low back injuries, neuromuscular disorders and musculoskeletal problems.

At baseline, we assessed the dynamic balance and knee function variables. The order of these assessments was considered by random numbers to eliminate the possible effect of time on the impact of intervention on the variables. Then, the subjects did either modified or routine warm-up, and their order was chosen by using the random number table. Immediately after doing the warm-up, we assessed the dynamic balance and knee joint function variables again. Each subject underwent both interventions in two sessions separated with at least 48 hours to eliminate the effects of the previous intervention session.

To evaluate the knee joint function variables, we used four single-leg hop tests, including one-leg hop for distance, triple-crossover hop for distance, triple-hop for distance and 6 meter timed hop test. Limb function during physical activities depends on proprioceptive inputs more than strength. The single-leg hop test could measure neuromuscular control, because to push the body forward and land safely on one limb, needs a high degree of proprioceptive sensitivity and functional ability [13]. This test can predict the dynamic stability of the knee joint, and has been used in studies as a clinical measure for lower extremity muscle strength and coordination, proprioception and improving knee joint function following rehabilitation interventions [14-16].

The subjects stood on the test leg, then jumped forward as far as they could, and landed on the same limb. The subjects were asked to land with control and keep the foot in contact with the ground. The distance from the toes in push off to the heel at the landing moment were measured. The distance was measured with a tape and timed with seconds. Each subject did the test twice, and the average of the two tests was recorded for analysis [15,16].

To evaluate dynamic balance, we used Star Excursion Balance Test (SEBT), which is a functional tool for assessing the dynamic stability of the lower extremities and to predict athletes who are prone to sport injuries. The test depends on neuromuscular characteristics such as lower limb coordination, balance, flexibility, and strength [8].

SEBT consists of a grid of 8 lines in anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral, and anterolateral directions. The dominant leg was placed in the center of the grid. The subjects placed their hands on the iliac crest to keep heel of stance leg in contact with the ground. The subjects were requested to reach as far as they could along the lines and return the reaching leg back to the double stance position. The reach distance was recorded from the center of the grid to the point of maximal reach. The average of three reaches was normalized by dividing it by leg length (measured from right ASIS to medial malleolus in supine position) to standardize maximum reach distance (excursion distance/leg length)*100.

Protocols

The modified warm-up program for a duration of 10 minutes according to previous studies [10,17] is as follows:

Lunge walking 10 steps, high knee running 20 meters, straight leg kick 10 times, butt kick running 10 times, tip toe walking 10 meters, turn squat two times, countermovement jump two times, carioka 10 meters, backpedal run 10 meters, and hip external rotation while skipping 10 times.

The routine warm-up program for a duration of 10 minutes according to previous studies[7,18] is as follows:

Four minutes of jogging forward and backward, and then stretching three big groups of lower limb muscles, with each stretch done three times and held for 30 seconds.

Quadriceps stretch: Each subject stood in front of a chair, bent the knee and put it on the seat, then closed the heel to the buttock and moved hip forward until hip hyperextension.

Hamstring stretch: Each subject stood and placed one foot on the seat, moved the trunk forward and moved the pelvis back.

Calf stretch: Each subject stood in the lunge position, kept the heel of the back leg in contact with the ground and fully extended the knee, and then moved the trunk forward.

Statistical Analysis

Kolmogorov-Smirnov test was performed to assess the normality of the data, and due to the lack of normal distribution of the data, Wilcoxon test was used to compare the dynamic balance and knee function between the modified and the routine warm-up groups. The level of significance was considered as $P<0.05$, and the SPSS software was used for the analysis.

Results

The statistical analysis by Wilcoxon test showed significant differences before and after the modified warm-up in eight directions of SEBT (P<005) (see Table1). The statistical analysis showed significant differences before and after the routine warm-up in four directions of SEBT ($P<0.05$) and the difference in the other four directions was not significant ($P>0.05$) (see Table 2).

The comparative analysis of dynamic balance differences before and after each warm-up showed that modified warm-up improved dynamic balance more than routine warm-up (see Table 3).

The statistical analysis by Wilcoxon test showed significant differences before and after modified warm-

Table 1: Results of SEBT (distance in cm) in eight directions in modified warm-up group before and after intervention

Direction	Before/After	mean±SD	P value	z
Anterior	Before	122.04±14.25	0.0001*	3.92
	After	140.00±11.14		
Anterolateral	Before	121.19±19.81	0.0001*	3.75
	After	135.09±19.04		
Lateral	Before	98.02±26.03	0.0001*	3.92
	After	116.27±26.20		
Posterolateral	Before	118.35±19.93	0.0001*	3.92
	After	139.08±22.00		
Posterior	Before	130.18±16.12	0.0001*	3.92
	After	149.73±17.14		
Posteromedial	Before	141.81±25.69	0.0001*	3.84
	After	159.67±24.71		
Medial	Before	137.79±26.89	0.0001*	3.92
	After	151.54±2580		
Anteromedial	Before	133.54±17.95	0.0001*	3.92
	After	147.80±18.81		

Significant P value is marked with *

Table 2: Results of SEBT (distance in cm) in eight directions in routine warm-up group before and after intervention

Direction	Before/After	mean±SD	P value	z
Anterior	Before	127.20±20.47	0.0001*	3.50
	After	134.72±18.62		
Anterolateral	Before	124.65±22.75	0.122	1.54
	After	128.91±23.76		
Lateral	Before	105.37±23.83	0.126	1.53
	After	110.38±23.79		
Posterolateral	Before	123.34±15.66	0.003*	2.94
	After	132.80±20.90		
Posterior	Before	135.32±16.20	0.001*	3.39
	After	142.88±16.88		
Posteromedial	Before	142.92±26.70	0.140	1.47
	After	146.04±24.44		
Medial	Before	138.45±28.56	0.117	1.56
	After	141.10±27.67		
Anteromedial	Before	133.94±23.63	0.015*	2.42
	After	139.12±22.96		

Significant P value is marked with *

Table 3: Comparison of the changes of SEBT (distance in cm) in eight directions in both groups before and after intervention

Direction	Modified warm-up mean±SD	Routine warm-up mean±SD	P value	z
Anterior	17.97±7.70	7.52±7.44	0.0001*	3.58
Anterolateral	13.89±9.63	4.26±11.37	0.005*	2.83
Lateral	18.25±10..07	5.01±12.57	0.002*	3.06
Posterolateral	20.73±15.25	9.45±15.86	0.005*	2.80
Posterior	19.54±12.46	8.55±9.02	0.005*	2.83
Posteromedial	17.87±16.33	3.12±8.69	0.0001*	3.50
Medial	13.74±8.12	2.65±8.24	0.001*	3.24
Anteromedial	14.26±7.97	5.18±8.15	0.001*	3.26

Significant P value is marked with *

up in four hop tests (P<0.05), (see Table 4). The statistical analysis showed significant differences before and after routine warm-up in two hop tests, and the difference in the other two tests was not significant (P>0.05), (see Table 5).

The comparative analysis of knee function differences before and after each warm-up showed modified warm-up improved knee function more than routine warm-up, (see Table 6).

Discussion

The findings showed that modified warm-up led to a greater immediate improvement in dynamic balance and knee function compared to routine warm-up.

The results of this study showed that modified warm-up as compared to routine warm-up has significantly greater impact on improving dynamic balance in eight directions of SEBT in athletes. Other studies have also demonstrated that warm-up reduces postural deviations and improves static and dynamic balance [4,19]. These results were due to warm-up exercises, which may result in neuromuscular facilitation improvement by reducing the excitability of spinal reflexes like stretch reflex and improving agonist-antagonist co-contraction. The balance improved by the reduction of the sensorimotor system limitations through

Table 4: Results of hop tests in modified warm-up group before and after intervention

Test	Before/After	Mean±SD	P value	z
One-leg hop (distance in cm)	Before	131.17±33.38	0.0001*	3.73
	After	143.35±33.31		
Triple hop (distance in cm)	Before	384.50±94.06	0.0001*	3.88
	After	415.87±95.47		
Triple crossover (distance in cm)	Before	320.07±115.11	0.0001*	3.88
	After	354.25±115.75		
6 meter timed hop (time in s)	Before	2.30±0.52	0.0001*	3.88
	After	2.04±0.46		

Significant P value is marked with *

Table 5: Results of hop tests in routine warm-up group before and after intervention

Test	Before/After	Mean±SD	P value	z
One-leg hop (distance in cm)	Before	133.95±32.30	0.076	1.77
	After	137.92±32.38		
Triple hop (distance in cm)	Before	402.52±80.70	0.050*	1.96
	After	411.25±83.81		
Triple crossover (distance in cm)	Before	343.20±102.32	0.003*	2.98
	After	424.52±107.28		
6 meter timed hop (time in s)	Before	2.24±0.44	0.109	1.60
	After	2.18±0.38		

Significant P value is marked with *

Table 6: Comparison of the changes of hop tests in both groups before and after intervention

	Modified warm-up mean±SD	Routine warm-up mean±SD	P value	z
One-leg hop (distance in cm)	12.17±10.37	3.97±10.05	0.007*	2.68
Triple hop (distance in cm)	31.37±22.24	8.72±18.48	0.003*	2.96
Triple crossover (distance in cm)	34.17±3..39	13.82±15.99	0.004*	2.85
6 meter timed hop (time in s)	0.26±0.14	0.05±0.15	0.0001*	3.58

Significant P value is marked with *

warm-up exercises [4].

The present study indicated the knee joint function, which was evaluated by single-leg hop tests, was significantly more improved by modified warm-up compared to routine warm-up. The results of this study are similar to those reported in previous studies [5,7,18,20]. They revealed that knee mechanoreceptor sensitivity or more central mechanisms improved after warm-up that resulted in proprioception improvement, which plays a role in prevention of injuries and improves athletic performance. On the other hand, some previous studies [12,21] have indicated that the balance score reduced, and the movement time and the reaction time increased in the warm-up group. They reasoned that this result was due to the loss of the positive effects of post activation potentiation by adding stretching to active warm-up, and the other theory was the ineffectiveness of passive stretching on muscle spindle firing characteristics and Golgi tendon organs (GTO) activation [12].

We can describe more effective mechanisms with modified warm-up compared to routine warm-up based on the type of warm-up exercises as follows:

Plyometric

Plyometric training, which was added as a part of the modified warm-up program, is an effective modality for improving joint position sense, balance and neuromuscular properties. Plyometric with stretch-shortening cycle uses the energy stored during the eccentric loading phase and stimulation of muscle spindles to facilitate maximum power production during the concentric phase of movement [22]. Plyometric stimulates joint mechanoreceptors. Desensitizing of GTO leads to increased sensitivity of muscle spindles, and thereby increases their afferents to CNS and then improves joint position sense and kinesthesia. These factors may enhance SEBT performance and knee function in athletes. There is a kind of coordination in plyometric exercises that include eccentric and concentric contractions, which can improve balance in SEBT reaching, because in SEBT reaching, torque generation while moving the body to maintain balance is controlled by eccentric contraction and so there occurs co-contraction of the lower extremity muscles [23]. Asadi et al. showed that after six weeks of adding plyometric training to basketball practice, SEBT improved significantly [22]. Myer et al. compared the effects of plyometric and balance training on power, balance and strength of athletes. The exercises were performed thrice a week for seven weeks. The results showed that both groups improved lower limb neuromuscular control and SEBT [24]. On the other hand, Kanghoon et al. showed that warm-up exercises like stretching, plyometric and treadmill did not improve dynamic balance in healthy subjects. They reasoned that fatigue following plyometric may have played a role in this ineffectiveness [8].

Strengthening Exercises

Strengthening exercises such as squat and lunge were parts of the modified warm-up exercises. These exercises increase loading on the lower limb and facilitate muscles to adapt to the forces entering the body [10]. Behm et al. reported that following some powerful contractions, there was improved neuromuscular activity due to the increase in H-reflex amplitude. This effect remained 10 minutes after the contraction, leading to faster response in unstable situations. So, through this mechanism of strengthening exercises in modified warm-up, lower extremity function in SEBT and hop tests can be improved [12]. As mentioned earlier, in SEBT reaching, torque generation while moving the body to maintain balance is controlled by eccentric contraction, and so the strength and the co-contraction of the lower extremity muscles are important for joint stability, proprioceptor activity and neuromuscular control in maintaining balance. Thus strength training in modified warm-up can increase muscle strength through adaptation by the nervous system, and improve knee function and balance [23]. Philippa et al. showed that eight weeks of neuromuscular training with focus on lower extremity strength improved SEBT function in healthy football players [25].

Dynamic Stretching

Dynamic stretching, which was also a part of modified warm-up, is more effective for muscle performance compared to static stretching in routine warm-up [10]. Some physiological mechanisms that explain the effects of dynamic stretching on lower extremity function include increased muscle temperature, change in muscle-tendon unit (MTU) stiffness and post activation potentiation (PAP). Dynamic stretching increases muscle temperature and also increases the sensitivity of nerve receptors and nerve conduction velocity, and thereby cause faster and more powerful muscle contractions in SEBT and hop test. MTU remains stiffer after dynamic stretching compared to static stretching, and leads to faster muscle force transfer into the skeletal system and make favorable changes in the force-velocity relationship, and this can improve the performance of the lower limb in dynamic balance and hop test. PAP is the other mechanism for more effectiveness of dynamic stretching, and is produced by the voluntary contraction of antagonist of the target muscle. PAP increases torque production and muscle performance, and facilitates motor neuron activity. Moreover, muscle contraction during dynamic stretching increases neural activity in the dorsal root of the spinal cord. These factors can improve athletic performance in dynamic balance and hop test [3,10,26]. When stretching is continued for more than 10 seconds, it reduces the sensitivity of muscle spindles, increases the flexibility of muscles and reduces pressure on the joints, and this impairs type II recruitment, which is required for the production of power and speed. Static stretching decreases muscle power by reducing motor units activity, neural factors such as changing in reflex sensitivity, and mechanical factors such as changing in the elasticity of the muscles by the length-tension relationship [27]. As Holt et al. showed, cardiovascular warm-up with dynamic stretching increased power and jumping performance, but cardiovascular warm-up with static stretching did not improve jump performance. They mentioned that static stretching could inhibit quick responses of muscle proprioceptors such as GTO and reduce motor unit recruitment by inhibiting the neural mechanisms [28]. Yamaguchi et al. showed that static stretching for 30 seconds was ineffective on muscle performance, while dynamic stretching increased muscle performance in five lower extremity muscles [26].

Limitations and Suggestions for Further Research

This study was conducted on ball sports athletes who were healthy, and it is possible that different results may be obtained in other sport groups and previously injured athletes. The immediate effects of modified warm-up in one session were evaluated, and the long term effects still remain unknown. Due to the role of core strength in sport injury prevention, it is recommended to examine the effect of this type of exercises in warm-up. It is also suggested that the effect of modified warm-up on lower extremity ROM and strength should be examined.

Conclusion

Modified warm-up including various components such as dynamic stretching, strengthening, plyometric and agility exercises could improve knee function and balance in athletes, making for more appropriate conditions for physical activity, and hopefully reduce the incidences of sport injuries.

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