Impact of Local Knee Heating and the Use of a Neoprene Knee Sleeve on Static and Dynamic Balance among Young Male Athletes

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Abstract

Introduction. This study aimed to determine whether the application of local passive knee surface heating combined with the use of orthopaedic support helps improving static and dynamic balance among young male athletes. Methods. To heat the subjects surface area of the knee, we used a custom-made knee cap with an installed (spirally) silicone tube system connected to a circulator which was kept for 10 minutes. Neoprene knee braces made from a sock-like elastic material that provides compression and warmth to the targeted area to improve functional performance were used in three different sizes: small, medium and large. Lower Quadrant Y-Balance Test (YBT) was performed by each subject to measure dynamic balance and Kistler force plate platform to measure static balance. Each test was performed three times: (1) Control (CON trial), (2) after Heating (HT trial), and (3) after Heating + Support (HTS trial). Results. ANOVA results showed statistically significant differences between HT and HTS trials compared to CON in postero-lateral reach distance only (p = 0.01) in Lower Quarter Y Balance Test. In static balance, statistically significant differences between trials in antero-posterior (p=0.03), medio-lateral (p = 0.01) and total sway velocity (p = 0.01) were found. Conclusion. The static and dynamic balance after the application of local knee heating and the orthopedic support was improved. These results indicated that local knee heating application combined with the use of orthopedic support could contribute to enhancing posture, balance and gait in young healthy male athletes. However, further studies are needed to clarify these effects on gender and more complex dynamic tasks.

Keywords: static/dynamic balance, passive heating, prophylactic knee sleeve

Introduction

Postural control or balance can be defined statically as the ability to maintain a base of support with minimal movement, and dynamically as the ability to perform a task while maintaining a stable position (Winter, et al., 1995). Among athletes balance is a necessary component of motor skills for maintaining posture and performing complex exercises (Ostad, 2019). This ability is influenced by a complexity of factors that are sensory information (from somatosensory, visual, and vestibular systems), joint range of motion (ROM), and strength (Palmieri, et al., 2002).

While static balance is the ability to maintain the orientation with centre of mass over the base of support at body rest, dynamic balance is the ability to transfer the vertical projection of the centre of gravity around the supporting base of support, as we age, motor performance and thermoregulatory efficiency progressively declines, creating job-related health and safety concerns (Hunter et al., 2016; Brazaitis et al., 2017). It is well established that whole-body hyperthermia impairs neuromuscular (Racinais et al., 2008; Nybo et al., 2008), cognitive performance (Hancock et al., 2003; Gaoua et al., 2010) and the ability to activate skeletal muscles (Racinais et al., 2008; Brazaitis et al., 2015). Most studies have used passive direct (e.g. water bath) or indirect (e.g. water-perfused suit) external heating of older subjects and have focused on the direct effects of mild-to-severe whole-body hyperthermia (WBH) on the kinetics of physiological responses including body temperature, sweating efficiency, cardiovascular parameters, metabolic rate, heat gain, subjective sensation, and cognition (Gagnon et al., 2016; Romero et al., 2016; Schlader et al., 2015). For decades it was believed that direct and indirect heating increases skin but not skeletal muscle blood flow. Recent results, however, suggest that passive
heating of the leg may increase muscle blood flow (Heinonen et al., 2011).

The increased elasticity would cause the joints to use more muscle activity to stabilize movement and potentially reduce motor error (Farley, Ferris et al., 1998). Logically, since ligaments and tendons are elastic structures, they should be more flexible with heat. Increasing temperature increases flexibility of knee ligaments (anterior and posterior cruciate) and there is a substantial change in tissue elasticity (Petrofsky et al., 2013). Indeed, the greater the proprioceptive control and joint range of motion, the better someone is able to establish a stable base of support. Furthermore, research has shown that braces and elastic bandages improve knee joint proprioception. Researchers hypothesize that bracing enhances proprioception by increasing cutaneous stimuli and pressure on the underlying musculature and capsule of the joint that it surrounds (Perlau et al., 1995). It has been suggested that improvements in proprioception, as a result of wearing a brace, may indicate that braces and sleeves provide additional somatosensory cues that reflexively bias proprioceptive pathways (Birmingham, et al., 2000; Bunker, et al., 2004). This study was designed to explore whether application of local passive knee surface heating combined with the use of a prophylactic knee sleeve helps improving static and dynamic balance in young male athletes.

Application of local passive knee surface heating combined with the use of a prophylactic knee sleeve may help in improving static and dynamic balance in young male athletes. Aim of the study was to explore whether application of local passive knee surface heating combined with the use of a prophylactic knee sleeve helps improving static and dynamic balance in young male athletes.

Methods

Materials and methods

Subjects: 30 young male athletes participants from different team sports, at the age range between 18-30 years old, mean age = 24.5 ± 3 years, number of years of sports experience 10 ± 2.5 years participated in the experiment. This study was conducted in the Institute of Sport Science and Innovations, Lithuanian Sports University. Ethical approval was obtained from the ethical committee of Lithuanian Sports University (Ethics Committee reference number BEK-KIN(M)-2019-144). Each subject was asked to sign a consent form before data collection. Participants were asked to not participate in sports training and do not consume alcohol prior 24 hours of the testing. Participants were non-smokers, were not on any psychotherapeutic drugs and had no history of significant knee injury or surgery, pain during knee/ankle extension/flexion, pain or instability during functional activities, or fracture of the pelvis, femur, tibia, fibula, patella, or Achilles tendon rupture.

Heating apparatus: By aiming to heat the subjects surface area of the knee we used custom made knee cap with installed (spirally) silicone tube system connected to circulator (WiseCircu, WCL-P22, Germany). The knee cap (dimensions were 46 cm length and 35 cm / 45 cm wide at calf and quadriceps part, respectively) was wrapped around the subject’s dominant leg downwards and upwards evenly from the centre of knee patella, and thereafter were secured by dedicated stickers. To maintain next-to-skin temperature of 44 ± 1 °C the circulator’s liquid (water) temperature was set at 57.5 °C. The total weight of knee cap with circulating liquid was approximately 600 g. The heating apparatus was placed at the dominant leg used to maintain balance by each subject and kept for 10 minutes (Paulauskas et al., 2020).

Orthopedic support: Neoprene knee braces made from a sock-like elastic material that provides compression and warmth to the targeted area to improve functional performance were used in three different sizes: small, medium and large. The subjects used the knee brace only during the HTS trial in both tests.

Experimental protocol: The study comprised a control experiment (CON trial), an experiment with local passive heating (HT trial) of the dominant leg and an experiment with local passive heating combined with the use of an orthopedic support. Before starting the experimental trial, participants attended a familiarization session. Upon arrival at the laboratory, anthropometric variables were measured, such as height (cm), weight (kg), and age. Then, experimental procedures for testing were demonstrated. Two different tests were used to measure static and dynamic balance. For the dynamic balance subjects performed Y-Balance Test and for the static balance, Kistler force plate platform similar to those they used (Lai et al., 2017;
The participants were asked to dress in a T-shirt, shorts, and socks. The tests were performed three times: (1) control test, (2) after Heating (HT), (3) after Heating and using an orthopedic support at the knee (HTS trial).

**Lower Quarter Y-Balance Test:** YBT is a screening tool that measures single-leg balance and reach in three directions: anterior, posteromedial and postero-lateral. The subject maintains a unilateral stance with the dominant leg centered on the platform and reaches each direction with the free leg. Each subject performed three different trials, and distance reaches in centimeters were recorded. According to the standardized protocol, a trial was considered invalid if the subject (1) failed to maintain unilateral stance, (2) touched down on the reaching foot, (3) failed to return to the starting position, such as removing hands from the hips, or (4) pushed or kicked the indicator to increase distance. A period of 30 seconds rest after each trial was performed in order to avoid fatigue.

**Kistler Force Plate Platform:** The static balance of the participants while standing was evaluated by use of Kistler force plate. Each subject was asked to stand quietly in one leg stance near the centre of a Kistler 9281A11 force platform, with the hands on the hips. A Metra byte DAS-8 12-bit AD converter, installed in an IBM-PC/AT compatible computer, was programmed to sample the eight Kistler 5001 charge amplifiers at 100 Hz for 15 seconds. The test consisted in 2 conditions: eyes opened and eyes closed, and each condition was repeated 3 times (3 trials). The test itself was performed 3 times: 1) control test, 2) after Heating (HT) and 3) after heating combined with the use of an orthopedic support (HTS).

**Statistical Analysis:** For the Lower Quarter Y-Balance Test, differences in the maximum reach distance in centimeters for each test were compared. Regarding Kistler force plate platform, the COP coordinate time series, antero-posterior (AP), medio-lateral (ML) and total sway velocity, were used to compute measures of postural steadiness, and characterize the static performance of the postural control system. A univariate repeated measures analysis of variance (ANOVA) was performed on each measure. Subsequent individual comparisons were conducted using the between-subjects and within-subjects variation terms from the repeated-measures ANOVA. Individual comparisons were conducted to assess the differences in the measures between the 3 different tests: 1) Control, 2) after Heating (HT) and 3) after heating combined with the use of an orthopedic support (HTS). The level of significance was set at $p < 0.05$ and all statistical analyses were performed using IBM SPSS Statistics 22 (Armonk, NY).

**Results**

Total participants were 30 young male athletes, their characteristics given in Table 1. The dynamic balance, Lower Quadrant Y-Balance Test descriptive results showed below (Table 2). Levene’s test for Homogeneity of Variance results showed that variance can be assumed equal in all conditions $p > 0.05$.

**Table 1**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>21.5 ± 2.0 y</td>
</tr>
<tr>
<td>Height</td>
<td>176.4 ± 1.7 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>71.82 ± 7.59 kg</td>
</tr>
<tr>
<td>Body mass index</td>
<td>23.21 ± 3.81 kg/m²</td>
</tr>
<tr>
<td>Sports experience</td>
<td>9.8 ± 2.4 y</td>
</tr>
</tbody>
</table>

**Table 2**

<table>
<thead>
<tr>
<th>Anterior (cm)</th>
<th>Lateral (cm)</th>
<th>Medial (cm)</th>
<th>AHS (cm)</th>
<th>LHS (cm)</th>
<th>MHS (cm)</th>
<th>AH (cm)</th>
<th>LH (cm)</th>
<th>MH (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.3 ± 16.6</td>
<td>97.3 ± 12.5</td>
<td>99.6 ± 14.3</td>
<td>64.6 ± 7.55</td>
<td>99.3 ± 14.6</td>
<td>104 ± 12.4</td>
<td>64.2 ± 6.4</td>
<td>97.1 ± 15.2</td>
<td>104 ± 17.2</td>
</tr>
</tbody>
</table>
ANOVA results $p = 0.01; F = 4.950$ have demonstrated statistically significant differences between trials and Tukey post hoc test results were statistically significant only in postero-lateral reach distance with a differences in heating and in heating + support condition $p = 0.01; 0.03$; as compared to control condition in Lower Quadrant Y Balance Test.

ANOVA results $p = 0.01; F = 7.95$ showed statistically significant differences between trials and Tukey post hoc test showed statistically significant differences in heating and in heating + support condition $p = 0.03; 0.01$; as compared to control condition in antero-posterior sway velocity in Kistler Force Plate Platform.

ANOVA results $p = 0.01; F = 107.9$ showed statistically significant differences between trials and Tukey post hoc test showed statistically significant differences in heating and in heating + support condition $p = 0.01; 0.01$; as compared to control condition in total sway velocity in Kistler Force Plate Platform.

**Discussion**

This study hypothesized that application of local passive knee surface heating combined with the use of an orthopedic support would help to improve balance and proprioception.

Regarding dynamic balance, ANOVA results showed statistically significant differences between
HT and HTS trials compared to CON in postero-lateral reach distance only (p = 0.01) in Lower Quarter Y Balance Test. In this study, statistically significant differences found between HT and CON trials in antero-posterior, (p = 0.03) medio-lateral (p = 0.01) and total sway velocity (p = 0.01) in Kistler Force Plate Platform. The application of heating improves static balance. Passive heating of the leg may increase muscle blood flow. It is likely that heating directly increases nitric oxide synthase and thus nitric oxide release within the muscle vasculature, which would augment muscle blood flow (Harris et al., 2010). Hyperthermia can have a direct effect on the voluntary activation of skeletal muscles, as the temperature affects the motor unit firing rate, which is necessary for contraction summation in tetanic contraction (Martin et al., 2005). Heat applied to peripheral tissues can also be used to increase the laxity in ligaments. The increased elasticity would cause the joints to use more muscle activity to stabilize movement and potentially reduce motor error (Ferris et al., 1998). Indeed, the greater the proprioceptive control and joint range of motion, the better is ability to establish a stable base of support.

The improvements observed in our study, after adding the use of a prophylactic knee sleeve, confirm the findings in previous studies. The effects of knee braces and sleeves on performance and joint protection during sport were widely discussed with different results. Kaminski et al. (1996) studied the effect of a knee brace on joint position sense of injury-free subjects and did not find any effect on active or passive joint repositioning. Also (Birmingham et al., 2000) did not find any significant improvement in knee proprioception wearing a neoprene sleeve, even though the subjects reported a subjective feeling of improvement in the ability of replicate joint angles. Researchers hypothesize that bracing enhances proprioception by increasing cutaneous stimuli and pressure on the underlying musculature and capsule of the joint that it surrounds (Perlau et al., 1995; Simoneau et al., 1997). However, although there is objective evidence in the literature that wearing a knee brace improves the proprioception of the joint, the mechanism by which bracing seems to influence proprioception remains enigmatic.

This study have demonstrated that the use of a prophylactic knee sleeve does not improve dynamic balance. A possible explanation for this might be that the strategies that our body uses in an unstable situation, such as ankle strategy or hip strategy, in order to maintain balance might be impeded by the brace placed on the knee. This way we theorize that braces provide compression and warmth to the targeted area but have less of a benefit in stabilizing movement during unstable positions.

Conclusions

In conclusion, the static and dynamic balance of healthy young adults improved after the application of local knee heating and the use of the orthopedic support.

• Improvement in dynamic balance was associated with an increase in reach distance in each direction: anterior, postero-medial and postero-lateral at the Y-Balance Test.

• Regarding static balance, a decrease in antero-posterior, medio-lateral and total sway velocity was observed.

• These results indicated that local knee heating application combined with the use of an orthopedic support could contribute to enhance posture, balance and gait in young male athletes. However, further studies are needed to clarify these effects on more complex dynamic tasks.

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KELIO VIETINIO ŠILDYMO IR NEOPRENINĖS KELIO APSAUGOS NAUDOJIMO POVEIKIS JAUNŲ SPORTININKŲ STATINEI IR DINAMINEI PUSIAUSVYRAI

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SANTRAUKA

Tyrimu siekta nustatyti, ar vietinio pasyvaus kelio paviršiaus šildymo taikymas, derinant su ortopedinio palaikymo (apsaugos) naudojimu, padeda gerinti jaunų sportininkų statinę ir dinaminę pusiausvyrą. Tiriamųjų kelio paviršinės dalies šildymui naudota standartinė kelio apsauga su įdiegta (spirališkai) silikonine vamzdžių sistema, sujungta su cirkuliatoriumi, kuris buvo laikomas prijungtas 10 minučių. Neopreninės kelio apsaugos, pagamintos iš kojinę primenančios elastingos medžiagos, užtikrinančios suspaudimą ir šilumą numatyjam plotui / kūno daliai, buvo trijų dydžių – mažo, vidutinio ir didelio. Kiekvienam tiriamajam buvo atliekamas YBT testas (Lower Quadrant Y-Balance Test) dinaminei pusiausvyrai išmatuoti ir naudota Kistlerio jėgos plokštė statinei pusiausvyrų įvertinti. Kiekvienas testas buvo atliekamas tris kartas: 1. Kontrolinis bandymas (CON trial), 2. Po šildymo (HT trial) ir 3. Po šildymo ir palaikymo (Heating + Support (HTS trial)). Rezultatai: ANOVA rezultatai parodė statistiškai reikšmingus skirtojus tarp HT ir HTS testų, palyginti su kontroliniu (CON) testu tik užpakalinėje šoninėje (angl. Posterolateral) kryptyje tik YBT (p = 0,01). Tiriant statinę pusiausvyrą, statistiškai reikšmingi skirtojai buvo aptikti tarp priekinės ir užpakalinės (angl. Antero-posterior) krypties (p = 0,03), vidutinio šoninio (angl. Medio-lateral) (p = 0,01) ir pilno mosto (p = 0,01) greičio rezultatų. Įkvėdas: Pritaikius vietinių kelio šildymą ir ortopedines apsaugas, statinė ir dinaminė pusiausvyra pagerėjo. Šie rezultatai rodo, kad vietinis kelio šildymas, derinant su ortopedine apsauga (palaikymu), gali prisidėti gerinant jaunų sportininkų (vyrų) laikyseną, pusiausvyrą ir eiseną. Norint geriau suprasti šį poveikį, atsižvelgiant į tiriamųjų lytį bei gerokai kompleksiškesnes dinaminės užduotis, reikalingi tolesni tyrimai.

Raktažodžiai: statinė / dinaminė pusiausvyra, pasyvus šildymas.