

Effect of Knee Supports on Knee Joint Position Sense after Uphill and Downhill Walking. A Test Using a Hiking Simulation Method

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Abstract

Hiking is a backcountry activity suitable for people in every age. Pain and injuries are reported in hiking especially during downhill walking. This increased injury risk is caused primarily by high loads on the lower extremities' joints and the optimal coordination control therefore required. Through the use of knee supports during hiking the injury risk might be reduced by, for example, improving proprioception. The purpose of this study was to determine the effect of wearing a knee sleeve and a knee brace on knee proprioception during a hiking simulation protocol on a treadmill. Twenty-four female sport students took part in this study. Joint position sense was measured without wearing any knee support, wearing a knee sleeve and wearing a knee brace at the beginning, after 30 minutes uphill walking and after 30 min downhill walking on a treadmill. Considering all tested subjects, without knee support the absolute repositioning error at the beginning was significantly better than the error after downhill walking ($p=0.022$) but no effect of the knee supports was found. Analysing only the subjects with a worsening in joint position sense after the activity, a significant improvement in joint position sense found wearing the sleeve and the brace after uphill and downhill walking ($p<0.05$).

Keywords: Knee; Injury prevention; Proprioception; Hiking

Introduction

Hiking is a popular backcountry activity suitable for people in every age. In the USA about a third of the adult population participate in hiking, and the participation rate is supposed to increase up to 10% in the next decades [1]. Pain and injuries are reported in hiking especially during the downhill phase. 80% of the injuries in hiking occur in the lower extremities and of them 19.2% occur at the knee [2]. In Austria 32% of injuries on the mountains occur during hiking or trekking [3].

Redfern and Di Pasquale [4] and Sheehan and Gottschall [5] demonstrated that the risk of falling and slipping is higher for downhill walking than for level and uphill walking. This increased injury risk is caused primarily by high loads on the lower extremities' joints [6,7]. This more demanding task needs an optimal coordination control. During uphill walking the exercise is mainly concentric while during downhill walking the exercise is mainly eccentric. The eccentric forces applied to the tissues of the knee, produce a higher knee load [6,7]. The combination of increased coordinative demand and joints' load might lead to pain and increase injury risk during downhill walking [5,4,8]. Furthermore, typically, the downhill phase of hiking follows the high intensity uphill phase. Therefore during downhill walking there is an additional muscular and psychological tiredness which increase general fatigue and may further decrease motor control and therefore further increase falling and slipping risk.

Through the use of a knee support during hiking the injury risk might be reduced. A reduction in subjective anterior knee pain wearing a brace during walking was demonstrated by Greenwald et al. [9], Powers et al. [10] and Van Tiggelen et al. [11]. Powers et al. [10] showed that the pain reduction was due to an increase in patellar contact area which decreased peak stress. The construction of the knee support with the use of rigid side bars, the presence of a hole for the stabilization of the patella or compressive design might help joint stabilization and control [12,13]. The compression exerted at the joint might as well enhance proprioception [14,15]. Particularly the knee support effect on proprioception becomes more advantageous after exercise [16,17]. Some authors demonstrated that knee proprioception decreases after

activity [18-21]. This reduction in proprioception might contribute to falling and slipping and therefore increase injury risk during downhill walking.

The purpose of this study was to determine the effect of wearing a knee sleeve and a knee brace on knee proprioception during a hiking simulation protocol on a treadmill. We hypothesized that wearing knee supports affects the joint position sense during exercise.

Methods

Twenty-four female students of the Department of Sport Science took part in this study (age 23 ± 2.5 , height 167 ± 6 cm, mass 58 ± 5.3 kg). None reported a history of knee injuries or physical diseases and all the subjects were not experienced in wearing knee braces. At the time of the test all subjects practiced regularly sport activity at least four times a week but no specification about the practiced sport was required. The test was approved by the Institutional Review Board.

The test consisted of 3 trials, separated by a week: one without knee support and one wearing each knee support at the dominant leg, in randomized order. The participants wore the sleeve and the brace for the entire test duration. The dominant leg was defined as the preferred leg used to kick a ball. The subjects walked 30 min uphill (20% inclination) and 30 min downhill (20% inclination) on a treadmill (Pulsar, h/p/cosmos, Germany).

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Received August 24, 2014; **Accepted** October 28, 2014; **Published** November 04, 2014

Citation: Bottoni G, Heinrich D, Kofler P, Hasler M, Nachbauer W (2014) Effect of Knee Supports on Knee Joint Position Sense after Uphill and Downhill Walking. A Test Using a Hiking Simulation Method. J Ergonomics 4: 132. doi:10.4172/2165-7556.1000132

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The walking speed was $v_{up} = 3$ km/h for uphill walking and $v = \frac{\sqrt{2g} - \sqrt{l+1}}{\pi}$ km/h, where l is the leg length [22], for downhill walking. Heart rate was continuously monitored during the protocol and registered after 30 min uphill and after 30 min downhill walking together with the subjective physical load, evaluated with a Borg Scale of Perceived Exertion (where 6 means “no exertion” and 20 means “maximal exertion”) [23].

At the beginning, after uphill and after downhill walking, joint position sense of the dominant leg was measured. The subject sat blindfold and with headphones on an adjustable chair with the legs hanging freely. From the starting position (90° knee angle) the lower leg was passively moved by the operator (about 5°/s) to a randomised target position between 20° and 70° of knee flexion (0° corresponded to the leg in completely extended position). This position was held for 5 s to allow the subject to memorize it, than the leg was returned by the operator to the starting position (Figure 1). After 5 s pause the subject had to actively repeat the pre-assessed position. Each subject performed the test at least six times before starting to be familiarized with the procedure. The positions of three markers one on the midpoint of the line between the trochanter and the lateral epicondyles, one on the lateral epicondyles of the femur and one on the lateral malleolus were recorded with a video camera. From these data the error between the passively assessed position (target position) and the actively assessed position (repeated position) was evaluated. Six repetitions each times were recorded and the mean value of the six repetitions was used for the analysis. The progress of the participants through the test is showed in the flow diagram (Figure 2).

Coordinates of the markers were digitised using Labview 2010 example code “Optical Flow Feature Tacking Example”. Target and repeated angles were subsequently computed in Matlab 2009. Proprioception was evaluated by measuring the absolute angular error, the relative angular error and the variable angular error [24]. The absolute error is the absolute difference between the repeated and the target position and represents the amount of the error in joint position reproduction. The relative error is the arithmetic difference between the two positions and gives a representation of the error direction. The variable error is the standard deviation from the mean of the relative errors. It represents an estimation of the data variability.

All data were analysed with the statistical software SPSS 18.0 (SPSS Inc., Chicago). A two-way analysis of variance (ANOVA) with repeated-measures was used to analyse the effect of uphill and downhill walking on joint position sense and the effect of the knee supports. Post hoc test were computed with the LSD method. Additionally, the subjects whose joint position sense was affected by activity were defined as subjects with “poor proprioception” (within the tested participants group) and separately analysed. Namely in this analysis were included subjects with an absolute error above the mean of the entire test sample when wearing no knee support. This selection was done separately for the test after uphill walking and for the test after downhill walking. A t-test for repeated measurement was used to compare joint position sense without knee support and with each knee support after uphill and downhill walking for the selected subjects. The level of significance was set at $p \leq 0.05$.

Results

A statistical difference was found for both the absolute and the

relative error between the repetitions ($p=0.03$ and $p=0.012$) but not between the conditions ($p=0.655$ and $p=0.931$). The LSD post hoc comparison showed that the absolute error ($p=0.022$) as well as the relative error ($p=0.006$) at the beginning were significantly smaller than after downhill walking. In the same way the relative error showed a significantly higher overestimation of the target angle after downhill walking than at the beginning ($p=0.006$).

The analysis of the interaction between repetition and conditions for the absolute error showed that the variation from the test at the beginning to the test after downhill walking was significantly higher



Figure 1: Test participant during a trial.

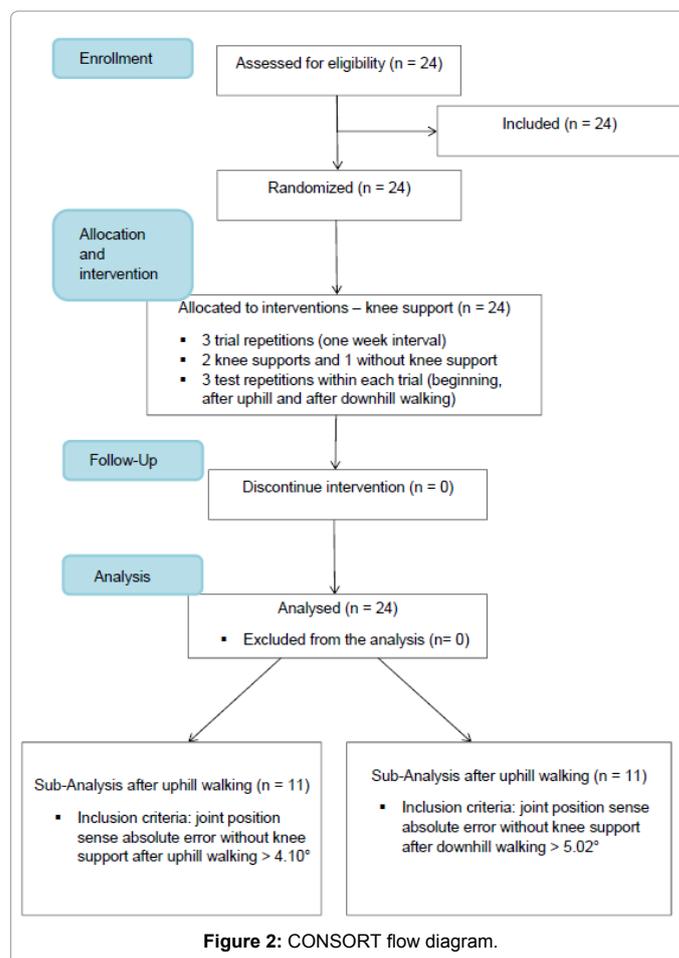


Figure 2: CONSORT flow diagram.

without knee support than wearing the brace ($p=0.048$). Mean and standard deviation of the errors are reported in Table 1.

11 subjects had “poor proprioception” after uphill walking. The mean joint position absolute error after uphill walking for these subjects was $5.73 \pm 1.22^\circ$ without knee support, $4.32 \pm 2.46^\circ$ wearing the sleeve and $4.79 \pm 1.64^\circ$ wearing the brace. The improvement wearing the knee supports was in both cases statistically significant ($p=0.026$ and $p=0.039$). For the 11 subjects with “poor proprioception” after downhill walking, the joint position sense absolute error was $7.34 \pm 2.38^\circ$ without knee support, $4.97 \pm 3.28^\circ$ wearing the sleeve and $4.85 \pm 2.26^\circ$ wearing the brace. Also in this case the brace and the sleeve improved proprioception significantly ($p=0.048$ and $p=0.046$).

The variable error did not show any difference comparing the three test repetitions ($p=0.640$).

The fatigue feeling after 30 min uphill walking was defined as “somewhat hard” (Borg Scale 13.2 ± 1.7) and after 30 min downhill walking as “fairly light” (11 ± 1.6).

Discussion

In this study joint position sense of healthy knees worsened significantly after downhill walking. This is in accordance with the results of Skinner et al. [21] and Roberts et al. [20]. These authors found impairment in knee proprioception after activity. This worsening in joint position sense is supposed to be related with a loss of efficiency of the mechanoreceptors located in the muscles and the joint. Exercise increases joint laxity and the chemical products, as lactate, weaken

the information transmissions from the muscles receptors. This deterioration in proprioception might then be related with a loss of efficacy in joint stability and control and therefore with an increased injury risk [25].

Including all subjects tested in the analysis, the knee brace and sleeve did not show any effect on joint position sense after uphill walking. The absolute error’s variation from the test at the beginning and the test after downhill walking was significantly lower wearing the brace than without knee support (Figure 3). This may suggest a tendency to an improvement in proprioception after activity wearing the knee support. Separating the subjects with poor joint position sense without knee support the improvement in proprioception wearing the brace and the sleeve was significant after uphill as well as after downhill walking. These results are consistent with the studies of Van Tiggelen et al. [16,17]. Subjects with a good proprioceptive acuity do not benefit from the use of knee supports. In the present study all the subjects presented a good baseline proprioception before the activity, therefore there are no improvements wearing the knee supports in joint position sense for the test at the beginning. For some subjects, exercise decreased proprioception and in this situation the benefit of the intervention became evident.

Proprioception is a feedback for the muscles stiffness modulation to control the joint and it is provided by mechanoreceptors located in the joint capsule, in the ligaments, in the tendons, in the muscles and in the skin [20,21]. Physical activity, with the initiation of a fatigue process, worsens the activity of the receptors located in the muscle and in the joint capsule [19,21,25]. Knee supports may supply an additional

	Participants (n = 24)								
	Beginning			Post-uphill			Post-downhill		
	W	S	B	W	S	B	W	S	B
Absolute error	3.54 (1.63)	3.99 (1.86)	3.68 (1.87)	4.10 (1.79)	4.07 (2.54)	3.98 (1.61)	5.02 (2.84)	4.37 (2.69)	3.96 (1.95)
Relative error	2.01 (2.49)	2.67 (3.13)	2.12 (2.79)	2.61 (2.73)	3.21 (3.32)	3.34 (2.05)	4.10 (2.75)	3.16 (3.19)	2.95 (2.79)

Table 1: Mean and standard deviation of the mean and relative joint position error for all the subjects involved in the study (N=24). W = without knee support S = knee sleeve B = knee brace.

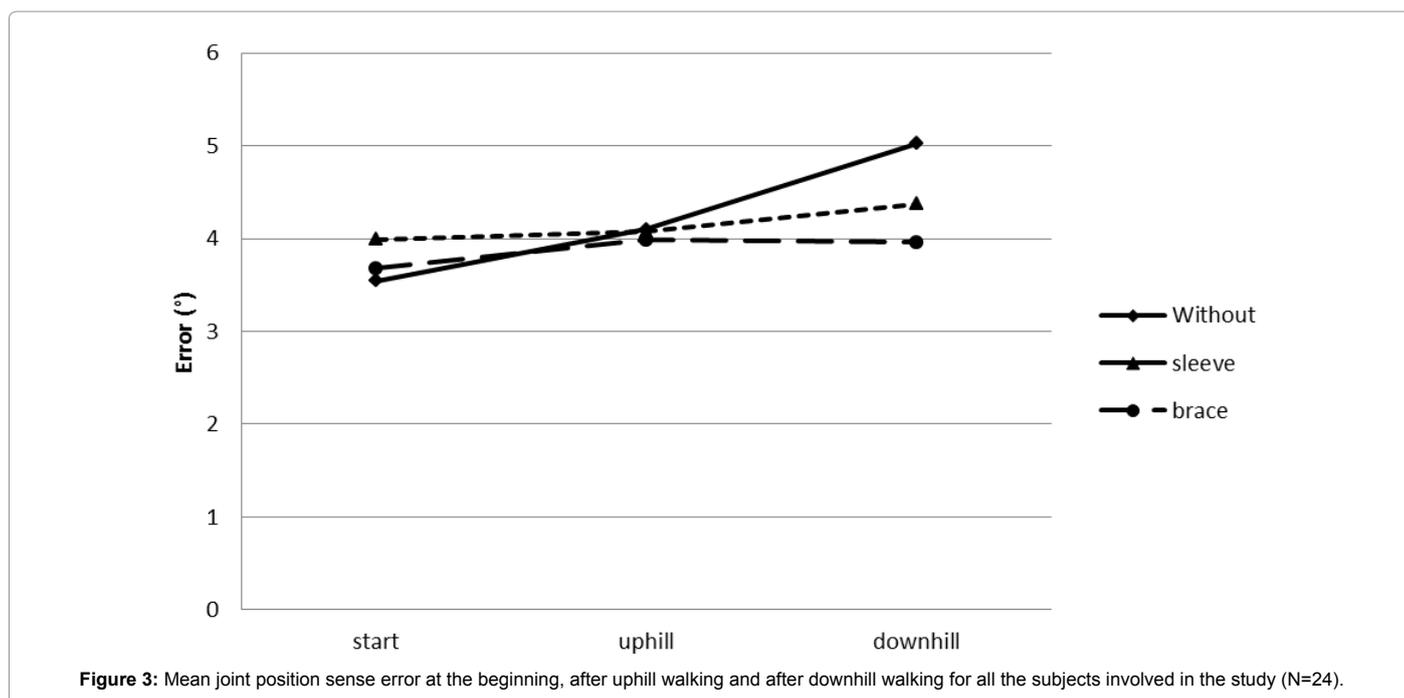


Figure 3: Mean joint position sense error at the beginning, after uphill walking and after downhill walking for all the subjects involved in the study (N=24).

stimulation to the skin receptors which play an important role in providing information about joint movement [26]. This additional stimulation might compensate the efficiency decline of muscle and joint receptors due to activity and the proprioceptive acuity at the knee during exercise.

The tested knee brace had rigid side bars and a hole for the stabilization of the patella. The sleeve had a compressive design. These characteristics might help joint stabilization during walking as suggested by Chew et al. [12] and Najibi et al. [13]. An enhanced stabilization may delay the fatigue process and keep the proprioceptive acuity at a higher level.

Some limitations should be considered when interpreting the results. The present study concerns trained young people who are supposed to have a good proprioceptive acuity. The effect of the knee supports might be even stronger for untrained, injured or aged people with lower proprioceptive acuity [14,16,17]. Moreover, the subjects walked on a treadmill with a constant inclination and an even ground and it should be accounted as a limitation when relating the results with a real hiking situation.

Further studies where the training level and the fatigued status of the participants are better contemplated would be useful to understand to what extent the effect of knee supports on proprioception during exercise.

Acknowledgment

This research was supported by the COMET K-Project "Sports Textiles" (grant number: 820494). The project was founded by the Austrian Research Promotion Company (FFG), Standortagentur Tirol (Austria) and region Vorarlberg (Austria).

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