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Original Article

Effectiveness analysis of muscle stretching during interferential current in soccer players – an explorative study

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Abstract:
Aim of this explorative study is to determine the feasibility of muscle stretching during interferential current therapy (ICT) versus no stretching on hamstring extensibility and evaluate acute effects. It should generate hypothesis for further empirical studies. 12 amateur soccer players were included. Interventions: Hamstring stretching during ICT vs. rested. Main Outcome Measure was Fingertip-to-floor test (FTF) and was measured at baseline, 15, 45 and 90 minutes after intervention. Hamstring extensibility increased significantly in both groups with a median of 8.20 cm after 90 minutes in the IG compared to 5.90 cm in the CG. Hamstring extensibility could increase during ICT. However, the selection of the measurement method FTF should be reconsidered and for further research a sensitive and valid measurement tool should be selected.
Key Words*:* feasibility studies, soccer, muscle stretching exercise

Introduction

Hamstring injuries often occur in stop-and-go sports such as soccer (Rogan, Wust, Schwitter, & Schmidtbleicher, 2013). In addition to high rehabilitation costs, injuries are associated with training and competition failures (Hawkins, Hulse, Wilkinson, Hodson, & Gibson, 2001). Electromyography and biomechanical studies show that, during the running cycle the hamstring muscles are the most active muscle group in the swing phase (Mann & Sprague, 1980; Montgomery, Pink, & Perry, 1994). Rogan et al (2013) observed that hamstring injuries occurred at the end of this phase The hamstring muscles are in a 12% more stretched position during a 130 ms long period in this phase than during standing position (Heiderscheit et al., 2005). At the same time, the hamstrings performed eccentric work to decelerate the swing of the leg before ground contact and high peak loads occur on the structure. The elastic inefficiency of the hamstrings may lead to muscle injuries. (Montgomery et al., 1994). Therefore, decreased hamstring muscle elasticity is regarded as one of the risk factors for musculoskeletal disorders (Ylinen et al., 2009).
Furthermore, the literature describes a risk of recurrence for hamstring injuries of more than 20% (Cloke et al., 2012). For this reason, muscle-stretching methods are used to maintain or optimize the range of motion in sports, as well in prevention, as in recovering from injuries (Klee & Wiemann, 2005). In order to achieve larger and faster effects of the elasticity of the hamstring muscles, a new stretching method was investigated in this study. During interference current therapy (ICT), soccer players were stretching their hamstring muscles.

The principle of ICT application is based on the impulse due to the high frequencies falling into the recovery period of the refractory period. This results in a reversible tonic depolarization under the electrode, at which point the rest potential cannot be reached (Bhadra & Kilgore, 2004). Transmitting of action potential remains off, which is referred to as a high frequency electrical conduction block (Bowman & McNeal, 1986). The consequence is a reduction in the muscle tone. In addition, type Aβ nerve fibers are stimulated. This causes an activation of the gamma-amino-butyric acid neurotransmitters from inhibitory interneurons at the level of the spinal cord. An activation of these inhibitory interneurons leads to decreased wide-dynamic-range neuron activation. This process induces pain inhibition and probably raises the tolerance to stretching pain.

Until now, no study has investigated the effect of stretching with ICT on hamstring muscle extensibility. It seems justified to carry out an explorative study in the first step. The goal of this current study was to accomplish an explorative study to assess the effects on stretching during ICT. Exploratory investigation has been carried out when no well-formed theories or no conceptual frameworks are available. These investigations state the initial groundwork for future research. The findings of an explorative study can inform a larger compensatory study.

The aims of this explorative study were to *i)* explore the feasibility on safety and tolerability in the target participants, *ii)* identify the magnitude of acute effects for muscle stretching during ICT versus no stretching on hamstring extensibility in amateur soccer players, and *iii)* generate hypotheses and data needed to design further studies.

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Material & methods

Design

This current explorative randomized study divided amateur soccer players into an intervention group (IG) and a control group (CG) on a pretest-posttest design. The participants and assessors were not blinded. Randomization was done by a statistician who was not involved in neither the recruitment nor the evaluation process during the study. Written informed consent was obtained from all amateur soccer players. The study protocol was proved by the University's review board.

Measurements were carried out at baseline after 15, 45 and 90 minutes of intervention and rest period, respectively. The fingertip-to-floor (FTF) distance was recorded. The FTF test has been shown to have excellent reliability with an ICC of 0.99 (Perret et al., 2001).

The feasibility focused on the recruitment and randomization process, compliance rate and safety to the stretching during the ICT. Since no requirements concerning recruitment, randomization and adherence rate exist, reference values were obtained from the pilot study of Rogan et al. (2012) who investigated a pilot study of acute effects of fast dynamic stretching on rate of force development in amateur ice hockey players. Recruitment rate of 80% of team players were eligible for the explorative study, a 0% attrition, and 100% adherence were acceptable for the authors.

To ensure safety of the amateur soccer players during the intervention, an interview was conducted on their subjective well-being. The response of the question was: no pain and no tightness, pulling pain and tightness, severe pain and tightness. If the amateur soccer players replied severe pain and or severe tightness, the examiner stopped the intervention immediately. It was ensured that the device could be stopped at any time.

Because, the duration of a soccer game is at least 90 minutes, the primary outcome was set in the pretest-posttest in FTF at 90 minutes. The secondary outcomes were the pretest-posttest in FTF after 15 and 45 minutes of intervention and rest.

Participants

Twelve amateur soccer players (mean age: 25.92 ±2.87 years, weight: 74.92 ± 7.31 kg and height: 1.78 ±0.04 m) were recruited from a local soccer club. The recruitment process was initiated with consent of the coach potentially eligible soccer players were invited for an interview. Inclusion criteria were: age between 18 and 30 years and healthy. Exclusion criteria were: acute health issues such as injuries or musculoskeletal disorders.

Each player trained two times a week and played one game every weekend. This study was conducted in accordance with the Declaration of Helsinki. From all participants a written informed consent was obtained.

Procedures

The electrodes were applied while the participants were in the prone position with a slight knee flexion. An electrode (Zimmer Medizin Systeme GmbH, Neu-Ulm, Germany) was glued 1 cm above the central point and the other electrode was glued 1 cm below the central point (Hermens et al., 1999). The players lay in supine position during stretching. The left leg was fixed in extension with a belt on the thigh. The right leg was flexed in the hip joint at 100°. This angle was adjusted with a goniometer (Figure 1). To reach a submaximal sense of stretching of the right leg, the participants extended the right knee joint actively via the quadriceps muscle. The submaximal sense of stretching was defined as an unpleasant but still tolerable sense of stretching in the muscles (Marschall, 1999). This position was reached and held by the therapist. Now the ICT was increased to a noticeable tingling, to superimpose the submaximal sense of stretching. Thereafter, the participants extended their knee actively until the tolerated sense of stretching was reached. This process was repeated for a total of three minutes. While the sense of stretching was felt despite the high current intensity, the position was kept constant by the therapist for the remaining time. Before the same intervention was performed on the left leg, the FTF was measured. Current interference was used via carrier frequency of 4000 Hz and an amplitude modulation frequency of 100 Hz (Endomed 482, Enraf-Nonius B.V., Rotterdam, The Netherlands). No intervention was conducted on the CG members, who sat on a chair over three minutes.

Figure 1 End position of the stretch position

Statistical analyses

Descriptive data are presented as mean, standard deviation (±), and interquartile (IQA). Pre-post differences within the groups were tested using the Wilcoxon signed-rank test and between groups using the Mann-Whitney U test. The significance level was set at $P \leq 0.05$. To determine the effect size, the formula $r = Z / \sqrt{n}$ was used. According to Corder and Foreman (2009) a small effect is present from 0.1 to 0.3, a medium effect from 0.3 to 0.5, and a large effect at > 0.5. The statistical analysis was performed using SPSS version 20 (IBM Corporation, New York, USA).

Results

Altogether, 12 amateur soccer players (60%) (ICT: n = 6; CG: n = 6) could be recruited from a total of 20 soccer players. Because of injuries, three amateur soccer players were excluded. The remaining players refused to participate. For this pilot study, the random allocation to the two groups by means of opaque envelopes distinguished as efficient and suitable. Characteristics of the study population are shown in Table 1

Adherence: 100%.

Safety: The participants did not report any negative events or sensations.

Table 2 indicates the baseline values and the post values of both groups. The results show significant increases of hamstrings extensibility in both groups.

Table 1. Age and anthropometric charactersitics of both groups in mean and standard deviation (±)

	Intervention group n = 6	Control group n = 6
age (years)	25.5 (± 2.88)	26.33 (± 3.08)
height (m)	1.78 (± 0.04)	1.78 (± 0.03)
weigth (kg)	72.58 (± 9.41)	77.25 (± 4.00)
Body Mass Index (kg/m^2)	22.84 (±2.28)	24.44 (± 1.33)

Table 2 Descriptive statistics of the fingertip-to-floor (FTF) distance in median and interquartilerange (IQR)

FTF (cm)	Intervention group (n = 6)	Within P Value ES	Control group (n = 6)	Within P Value ES	Between groups P Value ES
Baseline	18.90 (25.75 - 13.5(	0.028[1]	22.60 (29.80 -18.35	0.028[1]	0.423 (0.23)
After 15 min	13.70 (17.75 - 7.58)	0.90	19.35 (25.58 – 15.8	0.90	0.11
Baseline	18.90 (25.75 - 13.5	0.028[1]	22.60 (29.80 -18.35	0.028[1]	0.423 (0.23)
after 45 min	13.45 (18.03 - 8.78)	0.90	16.70 (23.88 – 12.6	0.90	0.15
Baseline	18.90 (25.75 - 13.5(	0.028[1]	22.60 (29.80 -18.35	0.028[1]	0.423 (0.23)
after 90 min	10.70 (16.58 - 7.50)	0.90	18.45 (23.45 – 11.0	0.90	0.20

Discussion

The aims of this explorative study were *i)* to explore the feasibility on safety and tolerability in the target participants, *ii)* to identify the magnitude of acute effects for muscle stretching during ICT versus no stretching on hamstring extensibility in amateur soccer players, and *iii)* to generate hypotheses and data needed to design further studies. This explorative study could determine that this study design is feasible but needs modification for further studies.

The recruitment process for this explorative study was initiated with consent of the coach. This approach seems more appropriate than recruitment without the involvement of the coach. Is a coach in the recruitment process not involved, the recruitment rate decrease. Rogan et al. (2013) could only recruit 9 (31%) of 29 amateur ice-hockey players without a coaches contribution. With the enthusiasm of the coach to attend, players are more willing to participate in a project (R. J. Vallerand, 2004). In addition, the player hasn't expended extra time, since the implementation of the study occurred during the official training session. This explorative study could recruit 12 of 20 amateur soccer players (60%) from the team squat. The objective of 80% recruitment rate has not been reached. With regard to injury it is known that soccer players' injuries occur twice in the season (Ekstrand, Hagglund, & Walden, 2011). In 10-20% of cases, failures of> 4 weeks can be observed. This knowledge needs to be considered in future studies (Faude, Meyer, Federspiel, & Kindermann, 2009). One way to increase the recruitment rate would be carrying out several information sessions and distributing written information sheets. Through these procedures all healthy players could be achieved. Moreover, it should be estimated how long the injured players miss the trainings and whether a subsequent recruitment makes sense.

Randomization: The operation with the opaque envelopes for group classification was used for randomization in the present explorative study. In a following study, a stratified block randomization could be a alternative. This would ensure that both groups have the same number of participants. In addition, certain properties such as bias of results, could distributed to the groups in the same way (Kleist, 2006). Such properties regarding this explorative study could be a prior determination of the age, body size, body weight and the basic FTF measurement.

Adherence: The adherence in this explorative study was very good. There were no dropouts. This possibly occurred due to the fact that the coach motivated the team to participate with his consent (R. Vallerand, 2007). Adherence can be strengthened by the awakening of personal interest in this topic. The collected data can be helpful for further training designs. Possible limitations of the extensibility of the hamstring muscles can be detected earlier, treatments and interventions can be adopted. Dadebo et al. (2004) noted in their study, the more soccer players stretched, the less hamstring injuries occurred.

Safety: In this explorative study, single use electrode-pads were applied. They are hygienic and the coating has a certain buffering capacity and is hypoallergenic. The use of ICT with this electrode-pads is considered as non-problematic (Bossert & Vogedes, 2008).

Basically, the starting position for the duration of application during ICT was suitable. More challenging was the constant hip flexion angle throughout the intervention of 100°, as participants tried to avoid the position with increased elongation. The goniometer during application helped to control the angle.

To check the safety more accurately and clarify any subsequent consequences, a questionnaire would be suitable. This present study used a questionnaire, but it was not standardized. However, a questionnaire should evaluate well-being of the participants before, during, directly after and one day after the intervention. Possible impacts or injuries due to the intervention could be detected.

This explorative study could determine that hamstring extensibility during stretching with ICT increases hamstring extensibility compared to baseline measurements. Both groups were able to improve their hamstring extensibility.

The IG shows an increase in range of motion with a median of 8.20 cm after 90 minutes, compared to the CG with 5.90 cm. According to Oesch et al. (2011), the minimum difference between two measurements should be eight centimetres. This fact confirms a clinical relevance for the IG and does not apply for the CG. In the current study the amateur soccer players performed an antagonist contraction method during ICT. The participants have concentrically activated their knee extensor muscle at the end-range position until the stretch sensation disappears. New studies refute the neurophysiological mechanisms, because no changes in electromyographic (EMG) magnitude at full range of motion were determined (Kay, Husbands-Beasley, & Blazevich, 2015; Mitchell et al., 2009; Osternig, Robertson, Troxel, & Hansen, 1990). The hypothesis that an active contraction of the quadriceps muscles inhibits the hamstrings muscle-tendon unit via principle of reciprocal inhibition (Osternig et al., 1990) is not the main reason. Increased tolerance to stretching is more and more postulated (Kay et al., 2015; Mitchell et al., 2009). The applied ICT in this case probably increased the tolerance of stretching in the IG. It is possible that due to the pain-relieving effect of the ICT, the participants could stay longer in the end-range position. The literature describes another possibility. Static stretching of stretched muscle reduces EMG (Behm, Button, & Butt, 2001), motoneuronal excitability (H-reflex activity) (Behm et al., 2013), muscle spindle type I and II afferents output (Guissard, Duchateau, & Hainaut, 1988), and corticospinal pathways by group II and IV muscle afferents inputs (Amann et al., 2013). This can influence central drive of the working muscles and potentially of non-exercised muscle as well (Amann et al., 2013). This central drive could also lead to more relaxed muscles, and allow an increasing range of motion.

Because the present study only involved male amateur soccer players, the results of this study cannot be a generalized to the entire population. The following points may have contributed to the results and will now be critically discussed.

First, an isolated change in the extensibility of hamstrings cannot be verified (Oesch et al., 2011) with the FTF. The FTF is a complex movement, where many joints and structures need to work together during movement execution. Not only is the part of the lumbo-pelvic region crucial, but also the neuromeningeal structures, fascia and hamstrings are involved (Oesch et al., 2011). For further studies, sensitive and valid measures should be used to detect hamstring extensibility.

Secondly, it is evident that after acute static stretching the physiological increase of the range of motion are based on following hypotheses: a) the increase of range of motion is due to tolerance to stretching resulting of the previous stretching performance, and b) the changes in mechanical properties such as reduced muscle stiffness. Through the short stretching impulse, the tension of the muscle decreases. This is the main reason for increased hamstring extensibility in the control group. A reduction of muscle stiffness and increased tolerance to stretching enables a larger muscle stretch. This effect may occur even after a single FTF measurement. This reaction only occurs in the first three to five repetitions.

Lastly, in this exploratory study a total of four FTF measurements were conducted. In addition, the tolerable muscle elongation stress increases from stretching to stretching procedure. Hence, it is possible to stretch further. These facts may explain the improvement of the FTF in both groups.

The limitations of this explorative study were the lack of blinding, the standardization of the measurement method and the small sample size. Since the measurements of the FTF were carried out in the same room and several players were together in one room, blinding of the participants seemed impossible. In future studies, at least two rooms should be available. Furthermore, only one participant should be assigned to a room. Power analysis for $\alpha = 0.05$ and a power of 80% with an effect size of 0.6 revealed that 62 participants would have to be tested in each group at least. In addition, it is critical to detect the submaximal sensation of stretching, because, depending on pain threshold information, and personal interpretation, the sensation of stretching is perceived differently. In order to attenuate this problem, an additional Borg scale could be used as parameter in further studies. The initial position for stretching during ICT was basically suitable. Observance of the hip angle of 100° was difficult because the participants were trying to avoid the increased elongation. Control measurements with the goniometer during application helped the participants to comply with the angle. In future studies, one person should measure the hip joint angle and another person should perform the hamstring stretching.

Conclusions

The analysis of this explorative study indicates a general feasibility of the procedure if some adjustments were made. The recruitment process must be adapted to reach all squad members. This requires repeated information sessions. Furthermore, the volunteers and investigators should be blinded. The outcome variable FTF must be verified. Further studies should use a sensitive and valid measurement device such as a Straight-Leg-Raise machine. Hamstring muscle tensile-stress and hip angle during stretching can be detected more reliable. By means of a tensile-stress-hip-joint-angle time curve it is possible to determine the muscle tensile-stress at the end-range of motion and also in other hip joint angle positions. This survey method is more sensitive and examines only the hamstring muscle. In addition, EMG activity should be measured.

Conflicts of interest

No conflicts of interest exist

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