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Influence of transcutaneous electrical nerve stimulation (TENS) associate with muscle stretching on flexibility gains

Influência da estimulação elétrica nervosa transcutânea (TENS) associada ao alongamento muscular no ganho de flexibilidade

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Abstract

Background: Increased pain tolerance caused by stretching is an important factor in flexibility gains. Transcutaneous Electrical Nerve Stimulation (TENS) is therapeutic method for pain treatment, but its use during stretching has not been investigated. **Objective:** To evaluate the effect of associating TENS with stretching to achieve flexibility gains for the hamstring muscles of healthy women. **Methods:** Thirty women were randomized into three groups (n=10): one control (C) and two stretching groups (St and St+TENS). The stretching groups underwent static stretching (three repetitions of 30 seconds) for two weeks, and the other (St+TENS) underwent TENS application for ten minutes (100hz, 40μs) before the stretching, with the stimulation also being administered during the stretching. Flexibility was evaluated according to the passive knee extension before and after each session, and photographs were taken for analysis using the AUTOCAD software. Pain perception was evaluated on a numerical scale from 0 to 10 points. The data were analyzed using Student's t test for independent samples and analysis of variance, considering $p<0.05$ as the statistical significance level. **Results:** The St and St+TENS groups increased their range of motion in relation to C, but there were no differences between these two groups, with regard to flexibility gain after two weeks (St+TENS: 17.53°±9.25; St: 12.76°±8.75); daily flexibility gain (St+TENS: 6.00°±1.79; St: 5.20°±3.17); and pain perception during stretching (median of five for both groups). **Conclusions:** The use of TENS associated with stretching did not provide extra gains in muscle flexibility, in relation to stretching alone.

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Key words: muscle stretching; range of motion; TENS.

Resumo

Contextualização: O aumento da tolerância à dor provocada pelo alongamento é um fator importante no ganho de flexibilidade. A Estimulação Elétrica Nervosa Transcutânea (TENS) é uma importante terapia no tratamento da dor, porém seu uso durante alongamento não foi investigado. **Objetivo:** Avaliar o efeito da associação alongamento e TENS nos músculos isquiotibiais de mulheres saudáveis sobre ganho de flexibilidade. **Materiais e métodos:** Trinta mulheres foram aleatoriamente distribuídas em três grupos (n=10): controle (C) e grupos de alongamento (Al e Al+TENS). Estes últimos foram submetidos a alongamento estático (três repetições de 30 segundos) por duas semanas, sendo um deles (Al+TENS) submetido à aplicação de TENS por dez minutos (100hz; 40μs) antes da manobra, com estimulação presente durante a mesma. A flexibilidade foi avaliada pela extensão passiva do joelho antes e após cada sessão, sendo retiradas fotografias para análise pelo software AUTOCAD. A dor percebida foi avaliada com uma Escala Numérica de 0 a 10 pontos. Os dados foram analisados mediante o teste *t* de *Student*, para amostras independentes e análise de variância, considerando nível de significância estatística o valor de $p<0,05$. **Resultados:** Os grupos Al e Al+TENS tiveram aumento da ADM em relação ao C, mas nenhuma diferença foi encontrada entre os dois primeiros quanto: ganho de flexibilidade após duas semanas (Al+TENS: 17,53°±9,25/Al: 12,76°±8,75); ganho diário de flexibilidade (Al+TENS: 6,00°±1,79/Al: 5,20°±3,17); e dor percebida durante alongamento (mediana de cinco para ambos). **Conclusões:** O uso da TENS associada ao alongamento não promove maior ganho de flexibilidade muscular, em relação ao alongamento isolado.

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Palavras-chave: exercícios de alongamento muscular; amplitude de movimento articular; TENS.

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Introduction

Muscle flexibility can be defined as the ability to move a joint or series of joints with comfort and ease in an unrestricted and painless range of motion (ROM)[1]. Flexible muscles are considered important factors in the reduction of the potential for injury, as well as in muscle rehabilitation and the development of better athletic performance[2-5].

In order to improve this flexibility, stretching exercises have been widely used in clinical and sporting practice and, despite the large number of studies, there is still some controversy surrounding this subject. Methodological differences between the studies are an indication of the existing disagreement between authors concerning the more important aspects of muscle flexibility gain through stretching.

Two mechanisms are essentially considered responsible for ROM increase after muscle stretching: in the first one, an alteration in the sensitivity of pain receptors increases stretching tolerance and, consequently, the effectiveness of the techniques[5,6]; and in the second one, changes in tissue viscoelasticity, such as the decrease in the passive tension of the muscle tendon unit immediately after stretching, are the primary reasons for the flexibility gain[7,8]. It is suggested that these effects occur due to a hysteresis effect, seen as an indication of tissue viscosity, with a reduction in the dissipation of tissue energy after stretching[7]. In addition, changes in the muscle tendon stiffness may occur with the adaptation of the series and parallel elastic components, and with the rearrangement of the collagen fibers[7].

Based on these aspects, some studies have been developed with the purpose of investigating the influence of techniques that, combined with muscle stretching, promote greater flexibility gain by decreasing pain during stretching (immersion in cold water[2], application of ice compresses in the form of packages[9]) or by the increasing complacency of viscoelastic muscle components (muscle heating such as deep heating[3,9], superficial heating[2,3] and warm-up active exercise[3,10]).

Among the available alternatives to increase the tolerance of subjects to painful stimuli, the Transcutaneous Electrical Nerve Stimulation (TENS) has been considered, over the last few years, an important clinical tool for the treatment of pain[11,12]. High-frequency, short-duration pulse TENS is known as "conventional TENS" and promotes a type of tactile stimulation able to activate the large caliber fibers and to decrease the sensation of pain[11,13]. Its action can be explained by the pain gateway theory[14], and its analgesic effect is local, taking place at the spinal segment that corresponds to the stimulated dermatomes[15]. The widespread knowledge about TENS has accentuated its use in the control of the neurogenic pain and consequently TENS can be considered the most common and important form of electrical analgesia[16]. However, the use of this tool to decrease pain caused by muscle stretching, with possible increase to tolerance to treatment resulting in greater improvement in ROM, has not been investigated in previous studies.

Therefore, the aim of this study was to evaluate the effects generated by the combination of muscle stretching and TENS on the hamstring muscle group of healthy subjects. This was achieved through the observation of daily flexibility gain (immediately after the stretching session) and total flexibility gain (after the intervention period) as well as the assessment of the perception of pain caused by muscle stretching.

Methods

Study characterization

The current study was carried out to evaluate the effects of the combination of TENS and muscle stretching on the hamstrings of healthy young subjects. This was a longitudinal study with a randomized, controlled and blind experimental design. Data were collected from March to April 2007, always at the same time of the day (between 11:30 and 2 PM).

Subjects

Thirty non-athlete females were randomly selected to take part in this study and were distributed into three groups: (1) group submitted to the TENS protocol and to the stretching protocol (St+TENS); (2) group submitted to the stretching protocol (St); and (3) the control group (C). Inclusion criteria were: women from 18 to 30 years of age, body mass index (BMI) below 25, and passive knee extension angle between 110 and 160° (considering 180° as complete extension and with the subject positioned at the assessment table described below). Exclusion criteria were: presence of musculoskeletal injury, vasomotor or cardiac disease, sensibility disorder, continuous pain, use of analgesic medication and/or muscle relaxants, and absence to one of the intervention sessions. The sample was limited to women because of their greater availability for this study; also, a previous study[17] concluded that women's hormonal variation did not influence muscle flexibility. All subjects were previously informed about the purposes of this study and signed a free informed consent form.

The present study was approved by the Research Ethics Committee from the Onofre Lopes University Hospital of Universidade Federal do Rio Grande do Norte, according to Resolution 196/96, Approval 037/06.

Instruments

A board developed by Brasileiro, Faria & Queiroz[9] was used to assess the flexibility of the hamstrings through the measurement of passive extension ROM of the knee. A Canon 3.0 megapixel digital camera was used to capture the images of the knee extension for further analysis using AUTOCAD 2007. We also used: a Quark (TENS VIF 973) portable double channel TENS unit; 5cm^2 self-adhesive electrodes; and Pimaco TP16 circular silver adhesives. The latter were used to highlight the anatomic points.

Procedures

Flexibility assessment protocol

A single researcher marked the following positions along the lateral side of the lower limb, according to Gajdosik[18]: 5cm distal to the greater trochanter of the femur, 5cm proximal to the lateral epicondyle, over the fibular head and 5cm proximal to the external malleolus. The marks were made to enable the measurement of the knee angle formed by both segments of the lower limb. They were then photographed and analyzed using Autocad 2007. The subject was placed in a supine position on the abovementioned board, keeping the hip of the assessed limb fastened at a 90° flexed position, with the knee joint free to enable the assessment of its extension angle. A single researcher, who was blinded to group allocation, slowly performed continuous passive extensions of the knee to minimize possible reflexive interferences[19], until the subject indicated a initial discomfort without pain[20]. The extensions were performed three times before and after the procedures[9,21]. Another 2m segment was added to the board and to the tripod used to support the digital camera. This segment was placed perpendicularly to the plane of the subject's knee extension and to the camera to guarantee that the movement and the image acquisition planes remained parallel. The camera rested 2m away from the subject's knee. Knee extension angles were registered based on the marks on the lower limb segments and were later analyzed using Autocad 2007. The average of the three values was used to represent the angles before and after the procedures. Measurements were taken every day before and after each session, and a last one was taken two days after the end of the intervention. The daily assessments of the passive knee extension ROM, before and after the stretching protocol were used to evaluate the daily flexibility gain, but those done before and two days after the end of the experiment were used to evaluate the total flexibility gain.

TENS application protocol

Conventional TENS was applied (100Hz, 40µs, intensity on the tolerable sensorial limit, without muscle contraction) with an asymmetric biphasic wave. A trichotomy was carried out in the electrode fixation areas. In order to keep the researcher who conducted the stretching session unaware of group allocation, the TENS device was covered so that it was not possible to identify whether it was turned on or off, but the electrodes were used on all subjects in groups St and St+TENS. Muscle contraction was avoided to guarantee that the researcher would not identify group allocation (St and St+TENS) and to keep the electric stimulation within the sensorial limit, characterizing a conventional TENS application. The self-adhesive electrodes were positioned as follows: one channel (two electrodes) positioned on the distal portion of the back thigh (site of pain), with the first one positioned at 5cm proximal to the popliteous line and the second one 5cm away from the first one; and another channel was positioned on the back face of the leg (dermatome of L5, S1, S2, corresponding to the spine segments responsible for the hamstring innervation) with the first electrode positioned at 5cm distal to the popliteous line and the other one 5cm away from the first one. After ten minutes of TENS application, with a variance of intensity and frequency (VIF) to avoid accommodation of the electric stimuli, the stretching maneuver was performed with the stimuli still present.

Stretching protocol

The stretching used in this study was a static one and was performed by a hip flexion of the right lower limb in a slow, continuous motion until the subject signaled they had reached their discomfort tolerance threshold. At this point, the subject sustained this position for 30 seconds[1,4,23]. The knee of the stretched limb was kept in complete extension with the ankle in a neutral position while the opposite limb was kept stabilized in extension by the researcher. This maneuver was performed three times[21] by each subject every day of the experiment, with 30 seconds intervals[19]. The subjects were submitted to this protocol once a day, five times a week, for two weeks. The subjects were instructed not to do any other type of physical activity during the experimentation period.

Protocol for pain perception measure

After completing the stretching protocol, subjects from groups St and St+TENS evaluated the perceived pain during muscle stretching on all experimentation days using an 11-

Table 1. Subject characteristics. Mean and standard deviation for age, mass, height, BMI and range of motion prior to intervention for each group.

Groups	St+TENS	St	C	p
Age (yr)	21.44 (±1.66)	23.00 (±1.22)	22.00 (±2.35)	0.121
Weight (kg)	58.77 (±7.31)	57.33 (±6.59)	51.45 (±6.92)	0.076
Height (m)	1.66 (±0.06)	1.65 (±0.06)	1.61 (±0.06)	0.066
BMI (kg/m^2)	21.34 (±2.41)	20.95 (±2.01)	19.77 (±2.16)	0.110
Initial ROM (deg)	137.41 (±12.53)	133.26 (±10.05)	137.20 (±13.54)	0.075

St+TENS=Stretching and TENS group; St=Stretching group; C=Control group.

Table 2. Mean and standard deviation for daily flexibility gain (after each stretching session), total flexibility gain (after two experimental weeks) and final ROM.

Groups	St+TENS	St	C
Daily flexibility gain	6.00° (±1.79)*	5.20° (±3.17)	-
Total flexibility gain	17.53° (±9.44)**	12.76° (±8.75)**	2.17° (±6.85)
Final ROM	154.46° (±9.48)**	144.03° (±10.66)**	140.38° (±12.48)

*significantly different when compared to St group;**significantly different when compared to C group.

point Numerical Scale for Pain Evaluation, in which zero meant absence of pain and 10 meant maximal pain[24].

Thus, group C was only submitted to two assessments of the passive knee extension angle, with a two week interval between assessments (the time corresponding to the intervention), while groups St and St+TENS, were submitted to two assessments of the passive knee extension angle, the stretching protocol and the assessment of pain perception.

Statistical analyses

Initially, in order to verify the normality of the data, the Kolmogorov-Smirnov (K-S) test was used. Once normality was confirmed, Student's t-test in non-paired samples was used to compare the initial and final means of the two groups (St and St+TENS). One-way ANOVA for repeated measures was used for between group comparison of the means of daily flexibility gain, initial knee extension ROM and final knee extension ROM. The statistical significance values were identified using the *post-hoc* Tukey test and in all the statistical analyses, the significance level was set to $p \leq 0.05$. Confidence intervals (CI) of 95% were applied.

Results

Twenty-eight subjects completed the study, however two were excluded because they did not attend one day of the intervention. Group C kept its ten subjects and groups St and St+TENS were left with nine subjects each. The characteristics of the sample at baseline are presented in Table 1. The groups were similar in age, weight, height, BMI, as well as ROM before procedures began (Initial ROM) according to the ANOVA test ($p>0.05$).

Table 2 shows the results for daily flexibility gain, total flexibility gain and final ROM. The St and St+TENS groups had a significantly higher total flexibility gain and final ROM than group C ($p<0.05$), indicating the efficacy of the protocols used for flexibility improvement. However, total flexibility gain, daily flexibility gain, and final ROM were not statistically different between the St and St+TENS groups, suggesting similar flexibility gain for both groups.

When comparing the values of the Numerical Scale for pain evaluation between the experimental groups, we observed that both had the median value equal to five (quartile 25=4 and 75=6 for the St+TENS group and quartile 25=5 and 75=6 for the St group), indicating that the perceived pain during stretching for the St+TENS group was statistically similar to the group that was only submitted to stretching (St group).

Discussion

In spite of the existence of several studies on this subject, authors still disagree on the main factors that limit stretching: the viscoelastic components[7,8] and the tolerance to stretching[5,6]. Some studies[2,3,10] used superficial heating techniques and warm-up exercises combined with stretching with the intention of reducing tissue resistance, but did not find higher flexibility gain compared to stretching alone although the effects when using therapeutic ultrasound were more efficient[3]. This resource has been reported as a method of increasing tissue extensibility and reducing pain perception, though it still lacks sufficient evidence in the literature[25].

Similarly, a previous study[2] did not observe any advantage in cold water immersion for flexibility gain, although other researchers[9] have observed a greater effectiveness in immediate flexibility gain when ice packs were applied before stretching. In the latter case, muscle cooling was responsible, not only for pain reduction, but also for the reduction in nervous conduction velocity, and consequently muscle spindle discharge. This reduced the facilitation stimulus of the muscle spindle and the muscle tension, which enhanced tissue extensibility.

While using TENS – an analgesic resource that reduces the transmission of painful conduction at the medullar level but does not interfere with tissue extensibility or nervous conduction velocity – the present study found that there was no increase in muscle flexibility gain compared to the group that did not receive TENS, which suggests that the use of this resource while stretching does not increase the effectiveness of the maneuver.

Based on these findings, it is possible that stretching limitation consists not only of pain but of a combination of limitation by neurological and viscoelastic components of the stretched tissue. Thus, it is possible that the combination of techniques that decrease the resistance imposed by these two components will increase muscle flexibility when compared to an isolated technique.

Regarding the perceived pain during stretching, as represented by the Numerical Scale, the present study demonstrated that there was no significant difference between the studied groups. Although TENS is well known in clinical practice as an analgesic resource, some studies state that there is no scientific evidence to support the use of TENS for pain relief in certain conditions[26,27]. In the same way, the present research indicates that the application of TENS was not effective in reducing the perception of pain during hamstring muscle stretching.

However, two aspects must be taken into account. First, it must be highlighted that the instrument used to measure pain in this study (Numerical Scale), as well as the other scales used for this purpose, are subjective instruments of self-evaluation[28], and therefore limited in terms of a real and effective assessment of pain perception. Secondly, because TENS was used without motor levels of electrical stimulation, the desensitization may have reached only the most superficial tissues. Thus, TENS did not allow the sensations of maximal discomfort to occur with a higher ROM than in the group that only did the stretching.

In the present study, the researchers chose to use TENS within the sensorial threshold so that evaluator would not be able to identify, during the stretching maneuver, which subjects received electrical stimulation. The frequency of 100Hz was chosen based on previous studies[16,29]. The pulse duration of 40μs, due to the lack of consensus in the literature, was chosen in a pilot study carried out before the beginning of the experiment. This pulse duration allowed a greater range of increase in current intensity without the occurrence of muscular contraction. Further studies assessing the effects caused by other electrical stimulation parameters or other analgesic resources should be carried out to obtain greater clarification on this theme.

The sample used in this study was considered small, and it was one of the limitations of the study. Another limitation was the procedure used to assess hamstring flexibility (knee passive extension until the onset of discomfort). The assessment used here has been shown as a method that depends on the subject's perception of discomfort. Therefore, the assessment method chosen may have contributed to the results. In addition to that, future studies are necessary to observe the response to the proposed treatment in other populations, such as older adults and patients with neuromuscular disorders.

Conclusions

Static stretching has been shown as an effective method to promote increase in hamstring muscle flexibility; however, its association with TENS was insufficient to produce a greater increase in flexibility when compared to stretching alone. TENS was not effective in reducing the perception of pain caused by hamstring muscle stretching.

References

1. Bandy WD, Irion JM, Briggler M. The effect of time and frequency of static stretching on flexibility of the hamstring muscles. Phys Ther.1997;77(10):1090-6.

2. Burke DG, Holt LE, Rasmussen R, MacKinnon NC, Vossen JF, Pelham TW. Effects of hot or cold water immersion and modified proprioceptive neuromuscular facilitation flexibility exercise on hamstring length. J Athl Train. 2001;36(1):16-9.

3. Knight CA, Rutledge CR, Cox ME, Acosta M, Hall SJ. Effect of superficial heat, deep heat, and active exercise warm-up on the extensibility of the plantar flexors. Phys Ther. 2001;81(6):1206-14.

4. Feland JB, Myrer JW, Merrill RM. Acute changes in hamstring flexibility: PNF versus static stretch in senior athletes. Phys Ther Sport. 2001;2: 186-93.

5. LaRoche DP, Connolly DA. Effects of stretching on passive muscle tension and response to eccentric exercise. Am J Sports Med. 2006;34(6):1000-7.

6. Halbertsma JP, Mulder I, Göeken, LN, Eisma WH. Repeated passive stretching: acute effect on the passive muscle moment and extensibility of short hamstrings. Arch Phys Med Rehabil.1999;80(4):407-14.

7. Kubo K, Kanehisa H, Kawakami Y, Fukunaga T. Influence of static stretching on viscoelastic properties of human tendon structures in vivo. J Appl Physiol. 2001;90(2):520-7.

8. Nordez A, Cornu C, McNair P. Acute effects of static stretching on passive stiffness of the hamstring muscles calculated using different mathematical models. Clin Biomech. 2006;21(7):755-60.

9. Brasileiro JS, Faria AF, Queiroz LL. Influência do resfriamento e do aquecimento local na flexibilidade dos músculos isquiotibiais. Rev Bras Fisioter. 2007;11(1):57-61.

10. Williford HN, East JB, Smith FH, Burry LA. Evaluation of warm-up for improvement in flexibility. Am J Sports Med. 1986;14(4):316-9.

11. Chesterton LS, Barlas P, Foster NE, Lundeberg T, Wright CC, Baxter GD. Sensory stimulation (TENS): effects of parameter manipulation on mechanical pain thresholds in healthy human subjects. Pain. 2002;99(1-2):253-62.

12. Walsh DM, Lowe AS, McCormack K, Willer JC, Baxter GD, Allen JM. Transcutaneous electrical nerve stimulation: effect on peripheral nerve conduction, mechanical pain threshold, and tactile threshold in humans. Arch Phys Med Rehabil. 1998;79(9):1051-8.

13. Sluka KA, Walsh D. Transcutaneous Electrical Nerve Stimulation: basic science mechanisms and clinical effectiveness. J Pain. 2003;4(3):109-21.

14. Melzack R, Wall PD. Pain mechanisms: a new theory. Science.1965;150(699):971-9.

15. Brosseau L, Milne S, Robinson V, Marchand S, Shea B, Wells G et al. Efficacy of the Transcutaneous Electrical Nerve Stimulation for the treatment of chronic low back pain: a meta-analysis. Spine. 2002;27(6):596-603.

16. Tommaso M, Fiore P, Camporeale A, Guido M, Libro G, Losito L et al. High and low frequency transcutaneous electrical nerve stimulation inhibits nociceptive responses induced by CO2 laser stimulation in humans. Neurosci Lett. 2003;342(1-2):17-20.

17. Chaves CPG, Simão R, Araújo CGS. Ausência de variação da flexibilidade durante o ciclo menstrual em universitárias. Rev Bras Med Esporte. 2002;8(6):212-8.

18. Gajdosik RL. Effects of static stretching on the maximal length and resistance to passive stretch of short hamstring muscles. J Orthop Sports Phys Ther. 1991;14(6):250-5.

19. Magnusson SP, Aagaard P, Nielson JJ. Passive energy return after repeated stretches of the hamstring muscle-tendon unit. Med Sci Sports Exerc. 2000;32(6):1160-4.

20. Branco VR, Negrão Filho RF, Padovani CR, Azevedo FM, Alves N, Carvalho AC. Relação entre a tensão aplicada e a sensação de desconforto nos músculos isquiotibiais durante o alongamento. Rev Bras Fisioter. 2006;10(4):465-72.

21. Gama ZAS, Medeiros CAS, Dantas AVR, Souza TO. Influência da freqüência de alongamento utilizando facilitação neuromuscular proprioceptiva na flexibilidade dos músculos isquiotibiais. Rev Bras Med Esporte. 2007;13(1):33-8.

22. Chesterton LS, Foster NE, Wright CC, Baxter GD, Barlas P. Effects of TENS frequency, intensity and stimulation site parameter manipulation on pressure pain thresholds in healthy human subjects. Pain. 2003;106(1-2):73-80.

23. Halbertsma JP, van Bolhuis AI, Göeken LN. Sport stretching: effect on passive muscle stiffness of short hamstrings. Arch Phys Med Rehabil. 1996;77(7):688-92.

24. Downie WW, Leatham PA, Rhind VM, Wright V, Branco JA, Anderson JA. Studies with pain rating scales. Ann Rheum Dis. 1978;37(4):378-81.

25. Baker KG, Robertson VJ, Duck FA. A review of therapeutic ultrasound: biophysical effects. Phys Ther. 2001;81(7):1351-8.

26. Deyo RA, Walsh NE, Martin DC, Schoenfeld LS, Ramamurthy S. A controlled trial of transcutaneous electrical nerve stimulation (TENS) and exercise for chronic low back pain. N Engl J Med. 1990;322(23):1627-34.

27. Khadilkar A, Milne S, Brosseau L, Wells G, Tugwell P, Robinson V et al. Transcutaneous Electrical Nerve Stimulation for the Treatment of Chronic Low Back Pain: A Systematic Review. Spine. 2005;30(23):2657-66.

28. Averbuch M, Katzper M. Assessment of visual analog versus categorical scale for measurement of osteoarthritis pain. J Clin Pharmacol. 2004;44(4):368-72.

29. Johnson MI, Tabasam G. An Investigation into the Analgesic Effects of Interferential Currents and Transcutaneous Electrical Nerve Stimulation on Experimentally Induced Ischemic Pain in Otherwise Pain-Free Volunteers. Phys Ther. 2003;83(3):208-23.