Whole body vibration and auriculotherapy improve handgrip strength in individuals with knee osteoarthritis

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Abstract

OBJECTIVE: To verify the action of non-pharmacological interventions, whole body vibration exercise (WBVE) and auriculotherapy (AT) on the management of knee osteoarthritis (KOA) analyzing the handgrip strength (HS).

METHODS: One hundred twelve participants with KOA were allocated in (a) WBVE group with peak-to-peak displacement of 2.5 to 7.5 mm, frequency from 5 up to 14 Hz, acceleration peak from 0.12 up to 2.95 g (2 d/weekly for 5 weeks), (b) AT group, points of both ears (Kidney, Knee-correspondent point and Shenmen) were stimulated with seeds, (c) WBVE + AT group and (d) respective control groups. HS was assessed in all the participants, in acute and cumulative responses.

RESULTS: The intervention with WBVE alone and combined with AT improved (P < 0.05), in a cumulative response, the HS.

CONCLUSION: WBVE alone or combined with AT might promote biological effects that interfere with the HS in individuals with KOA.

INTRODUCTION

Osteoarthritis mainly affects the joints that are continually stressed, including the knees. The knee pain associated with knee osteoarthritis (KOA) is an important cause of disability in older adults and the main other symptoms include swelling, stiffness, deformation and loss of function. These conditions may hinder activities of daily living, including the ones related to the professional work. The handgrip strength (HS) may
be a physical marker of the strength and functionality of the lower limbs in individuals with risk for falls or with immobility related to physical disability. Measurement of HS can be also used to assess of upper limb strength, as an indicator of general health status and can represent the total strength of 22 muscles of the body. Garcia et al. have suggested HS as a simple clinical measure to identify the diminished functionality, which may lead to early interventions preventing disability. Although, Benedetti et al. have found a low correlation between HS and the strength of upper and lower limbs in elderly practitioners of physical activity.

Exercise is one of the main non-pharmacological therapies used to the management of KOA individuals. Several physical therapy procedures have been proposed to try to increase the quality of life, to improve the knee function, and to reduce pain in KOA individuals. Short wave diathermy, ultrasound, neuromuscular electrical stimulation, laser and whole body vibration exercise (WBVE) would be included in these interventions. Likewise, acupuncture and auriculotherapy (AT) have been successfully used to improve clinical conditions of KOA individuals. WBVE provides benefits of strength training with no addition of harmful loads to the knee joint. Authors have reported that WBVE would improve various social, personal and clinical conditions related to KOA.

WBVE is produced when individuals are exposed to mechanical vibrations generated in oscillating/vibratory platform (OVP). Controlled conditions must be considered in the protocols involving WBVE, including, biomechanical parameters (frequency-f, peak to peak displacement-D and acceleration peak-a<sub>p</sub>), work and rest time, number of bout and sessions. WBVE, in general, has important effects including, (a) reduction of pain, (b) improvement of muscle strength, bone mineral density and flexibility, and (c) reduction of the number of falls. Effects of the mechanical vibration exposure on upper body muscular activity, as an increase in skeletal muscle activity in the arms and on the HS have also been reported. WBVE can also improve clinical condition of KOA individuals, however some authors have failed in verifying clinical improvements in these individuals.

In AT, one of the approaches of the Traditional Chinese Medicine, is a system of diagnosis and treatment based on the stimulation of points located on the ear. AT is a type of acupuncture, in which, the ear is considered as a system of the body. AT, different types of materials (needles, plant seeds-Semen vaccariae, magnetic pellets, or low-energy laser) can be applied on points of the ears. In general, AT involves the stimulation of a point, the "corresponding region", that is a point closely related to the organic dysfunction to be treated. In addition, depending on the disease, other points are chosen. Authors have described benefits of the AT to several clinical disorders, as pain and anxiety, pain associated with cancer, knee arthroscopy, hip fracture and hip arthroplasty. In addition, it could be expected that WBVE would be an important alternative to the management of KOA individuals due to the action in the muscle performance. The aim of this investigation was to verify the effectiveness of these non-pharmacological interventions on the HS. It is hypothesized that combined intervention (WBVE and AT) could improve the functional capacity of KOA individuals, increasing the HS.

**MATERIALS AND METHODS**

**Individuals and ethics committee**

This study was approved by the Ethics Committee in Research of the Hospital Universitário Pedro Ernesto (HUPE), Universidade do Estado do Rio de Janeiro (UERJ) (Certificado de Apresentação para Aprovação Ética-CAAE-19826413.8.0000.5259) and Trial registration -RBR-7dfwct

**Sample size**

For a statistical power of 95% and significance level of 5%, a sample size of 13 subjects in each group according to the variable functionality was calculated. Considering a possible decrease in sample size, one hundred twelve KOA participants were recruited. The individuals were referred by a physician of the Orthopedics Department of the HUPE/UERJ.

**Inclusion and exclusion criteria**

As inclusion criteria for participation, the subjects should be 40 years old or more, with clinical diagnosis of KOA according to the criteria of the Ahlback. As exclusion criteria, the individuals could not present other musculoskeletal disorders, neurological diseases or not treated hypertension, refuse to sign the informed consent or to investigator criteria.

**Intervention and control groups**

Eligible participants were allocated in six groups: (a) WBVE group, (b) AT group, (c) WBVE + AT group (combined group) and (d) respective control groups.

**WBVE intervention**

WBVE was performed 2 d/weekly (5 weeks) with, at least, 48 h of rest between each WBVE session. The individuals were positioned sitting in a chair in front of an alternating OVP (Novaplate Fitness Evolution, DAF Produtos Hospitalares Ltda, São Paulo) with a comfortable flexion of the knees and the feet with no shoes (barefoot) on the its base (D of 2.5, 5.0 and 7.5 mm) (Figure 1). Their hands were conveniently in contact with their knees to facilitate the transmission of the mechanical vibration to the whole body (Figure 1).
The individuals performed one bout of 3 minutes (work time) in each D, and a one-minute rest (rest time) between the bouts. The frequency daily increased of 1 unit, from 5 up to 14 Hz ($a_{\text{peak}}$=0.12 to 2.95 g) (Table 1). The vector sum of the accelerations was measured using a 3-axial accelerometer (Vibration Data logger DT-178A, Ruby Electronics, Saratoga, USA). The individuals of the control group were exposed to the same protocol of the subjects, but with no vibration on the OVP (OVP turned off).

In the auricular intervention, AT group, the ears of the participants were stimulated with seeds (Semen vaccariae with approximated diameter of 1 mm) fixed on adhesive tapes on the points [corresponding point-Knee, Kidney and Shenmen (HT 7)]. The knee joint is located at the superior crus of the antihelix, with the same level of the superior border of inferior crus of the antihelix, the Shenmen (HT 7) is located at the bifurcation of the crura of the antihelix and the kidney is lying in the upper part of the cymba conchae at the superior portion of the acupuncture point of the small intestine. The characteristics of the seeds and of the adhesive tape used to stimulate the points of the ear are reported in Neto et al. As it was described, the individuals were instructed to press the adhesive tapes for 10 min, three times per day (6 d) and to remove the adhesive tapes one day (the seventh day) before returning to the next intervention.

**Combined intervention**

The participants of the combined intervention (WBVE + AT) and the respective control group were simultaneously submitted to both intervention (WBVE and AT interventions) (Figure 2).

**Handgrip strength**

HS was measured as proposed by American Society of Hand Therapists-ASHT, 2013. A manual dynamometer (EMG832WF, EMG System, São José dos Campos/SP) was used. The subjects were in seated position, arm in adduction, with 90° forward at elbow joint, forearm in neutral position, wrist with extension between 15° and 30° and ulnar deviation between 0 and 15°. HS was measured three times, with 30 s of rest, in the right hand during 6 s each time with verbal encouragement. The dynamometer’s dial was turned away from the individual to avoid visual or auditory feedback (ASHT, 2013). Measurements, in kilogram-force (kgf), were determined before and after the first session and before and after the last session (5 weeks). The highest value among the three measurements was considered to be analyzed. Differences (Δ) between the values (a) before and after the first session (acute effect), (b) before and after the last session (acute effect) and (c) before the first session and after the last session (cumulative effect) were determined.

### Table 1 Whole body vibration exercise protocol

<table>
<thead>
<tr>
<th>Session</th>
<th>Frequency (Hz)</th>
<th>$a_{\text{peak}}$ (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>D = 2.5 mm</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>0.12</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>0.18</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>0.24</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>0.32</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>0.40</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>0.50</td>
</tr>
<tr>
<td>7</td>
<td>11</td>
<td>0.60</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>0.72</td>
</tr>
<tr>
<td>9</td>
<td>13</td>
<td>0.84</td>
</tr>
<tr>
<td>10</td>
<td>14</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Notes: $a_{\text{peak}}$: peak acceleration; D: peak-to-peak displacement.
**RESULTS**

The flowchart of the participants throughout the study is reported in Figure 3. One hundred twelve subjects were randomly assigned to six groups: (a) WBVE group, (b) AT group, (c) WBVE + AT group (combined group) and (d) respective control groups.

**Evaluation of the acute effect of the interventions in the handgrip strength**

Table 2 shows the acute effect, in all the interventions, the difference (Δ) between the HS (kgf) after and before the first session was determined. No significant alteration was found (P > 0.05, Mann Whitney test) in the individuals of all the groups submitted to the interventions in comparison with respective controls.

Table 3 shows the acute effect, in all the interventions, the difference (Δ) between the HS (kgf) after and before the last session was determined. No significant alteration was found (P > 0.05, Mann Whitney test) in the individuals of all the groups submitted to the interventions in comparison with respective controls.

**Evaluation of the cumulative effect of the interventions in the handgrip strength**

Table 4 shows the cumulative effect, in all the interventions, the difference (Δ) between the HS (kgf) before and after each intervention the first session and the Δ between the HS before and after the last session were determined. A significant improvement was found (P < 0.05, Mann Whitney test) in the individuals of the group exposed to WBVE and the group submitted to the combined intervention (WBVE + AT).
In the current work, acute and cumulative effects of non-pharmacological interventions (AT, WBVE and combined WBVE + AT) on the HS of KOA individuals were evaluated. Neither treatment, alone or combined, altered the handgrip strength in the acute effect. However, significant improvements were found in the cumulative evaluation to the interventions involving WBVE alone or combined (WBVE + AT). These findings are in agreement with Neto et al.39 that have reported significant decrease on the level of pain in the KOA participants treated with WBVE alone or with the combined intervention in acute and cumulative effects. Moreover, in general, in WBVE protocols, the individuals are in squat position.40,46,47 The position used in this work, in which the individuals sat in an auxiliary chair, was proposed with the intention of reducing the load and the impact on the knee joint. In addition, it is provided a comfortable, pleasurable method with a possible greater adherence in the practice of physical exercise.48 It is suggested that the increase of functional performance could be associated to muscles stimulation caused by mechanical vibration.49 Fransen et al.50 pointed out that any type of exercise program performed regularly and monitored by healthcare professionals can improve pain, physical function and quality of life related to KOA in the short term. The number of studies assessing physical function after vibration training is still limited. In addition, AT is a very simple technique that is used in several clinical populations.51,52

Considering the acute effect related to the first session, it was expected no modifications on the HS due to the intervention. The nonparametric Wilcoxon Signed-Rank test was used instead to compare the control with intervention in each group. Data are expressed as mean ± standard deviation of the difference (Δ) between the hand grip strength (kgf) after and before the first session, and the level of significance P ≤ 0.05. Statistical analysis was only performed on participants who obtained 100% of frequency.

**Table 2** Acute effect of the interventions in the first session (kgf, ± s)

<table>
<thead>
<tr>
<th>Group</th>
<th>Control group (n=15)</th>
<th>Interventions group (n=21)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBVE</td>
<td>1.54±3.79</td>
<td>1.95±2.92</td>
<td>0.57</td>
</tr>
<tr>
<td>AT</td>
<td>0.76±1.50</td>
<td>−1.48±3.14</td>
<td>0.07</td>
</tr>
<tr>
<td>WBVE + AT</td>
<td>0.16±5.12</td>
<td>1.27±4.94</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Notes: WBVE: group submitted only to whole body vibration exercise; AT: group submitted only to auriculotherapy; WBVE + AT: group submitted to combined interventions (whole body vibration exercise and auriculotherapy). The nonparametric Wilcoxon Signed-Rank test was used instead to compare the control with intervention in each group. Data are expressed as mean ± standard deviation of the difference (Δ) between the hand grip strength (kgf) after and before the first session, and the level of significance P ≤ 0.05. Statistical analysis was only performed on participants who obtained 100% of frequency.

**Table 3** Acute effect of the interventions in the last session (kgf, ± s)

<table>
<thead>
<tr>
<th>Group</th>
<th>Control group (n=15)</th>
<th>Interventions group (n=18)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBVE</td>
<td>0.36±2.69</td>
<td>−0.26±2.81</td>
<td>0.27</td>
</tr>
<tr>
<td>AT</td>
<td>0.76±2.15</td>
<td>0.45±2.60</td>
<td>0.85</td>
</tr>
<tr>
<td>WBVE + AT</td>
<td>−0.41±3.69</td>
<td>−2.71±2.33</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Notes: WBVE: group submitted only to whole body vibration exercise; AT: group submitted only to auriculotherapy; WBVE + AT: group submitted to combined interventions (whole body vibration exercise and auriculotherapy). The nonparametric Wilcoxon Signed-Rank test was used instead to compare the control with intervention in each group. Data are expressed as mean ± standard deviation of the difference (Δ) between the hand grip strength (kgf) after and before the last session, and the level of significance P ≤ 0.05. Statistical analysis was only performed on participants who obtained 100% of frequency.

**Table 4** Cumulative effect of the interventions (kgf, ± s)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>First session</th>
<th>Last session</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBVE</td>
<td>18</td>
<td>1.95±2.92</td>
<td>−0.26±2.81</td>
<td>0.03</td>
</tr>
<tr>
<td>AT</td>
<td>19</td>
<td>−1.48±3.14</td>
<td>0.45±2.60</td>
<td>0.09</td>
</tr>
<tr>
<td>WBVE + AT</td>
<td>16</td>
<td>1.27±4.94</td>
<td>−2.71±2.33</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Notes: WBVE: group submitted only to whole body vibration exercise; AT: group submitted only to auriculotherapy; WBVE + AT: group submitted to combined interventions (whole body vibration exercise and auriculotherapy). The nonparametric Wilcoxon Signed-Rank test was used instead to compare the first session with last session in each group. Data are expressed as mean ± standard deviation of the difference (Δ) between the hand grip strength (kgf) after and before each the session, and the level of significance P ≤ 0.05. Statistical analysis was only performed on participants who obtained 100% of frequency.

**DISCUSSION**

In the current work, acute and cumulative effects of non-pharmacological interventions (AT, WBVE and combined WBVE + AT) on the HS of KOA individuals were evaluated. Neither treatment, alone or combined, altered the handgrip strength in the acute effect. However, significant improvements were found in the cumulative evaluation to the interventions involving WBVE alone or combined (WBVE + AT). These findings are in agreement with Neto et al.39 that have reported significant decrease on the level of pain in the KOA participants treated with WBVE alone or with the combined intervention in acute and cumulative effects. Moreover, in general, in WBVE protocols, the individuals are in squat position.40,46,47 The position used in this work, in which the individuals sat in an auxiliary chair, was proposed with the intention of reducing the load and the impact on the knee joint. In addition, it is provided a comfortable, pleasurable method with a possible greater adherence in the practice of physical exercise.48 It is suggested that the increase of functional performance could be associated to muscles stimu-
tension were significantly increased due to the WBVE. Kurt et al.44 have reported that WBVE can potentiate handgrip performance. It was described a significant interaction of pre-post intervention for the handgrip test, indicating a significant performance increase of moderate effect after WBVE intervention. Moreover, Fattorini et al.45 have pointed out that muscular activation of the forearm of healthy subjects can increase with the vibration stimuli in a study, in which, the individuals were exposed 20, 30, 33 and 40 Hz. Similar finding was verified considering the combined interventions in the current study. However, Giminiani et al.46 showed no significant difference on HS in healthy individuals exposed to high and low vibrations.

The improvement of the HS might be associated with this reduction of the pain. As the osteoarthritic pain would be associated with central and peripheral nervous systems responses,71 as well as due to biological processes activated,72 the cited interventions (WBVE + AT) would act in the referred biological levels. Moreover, some studies suggest that WBVE may improve the anti-inflammatory status of elderly individuals.73 It is suggested that the analgesic effects of the AT would be induced by activating the descending pain inhibitory pathway of the brainstem.25,26 This stimulation induced analgesic effect increases the concentration of β-endorphins and can be blocked by naloxone.69 Considering our findings, the increase of the HS would be related to the reduction of the pain in WBVE or combined interventions. Neto et al.59 reported that in the cumulative effect, the level of pain in the participants of the various groups before the first (with 5 Hz) and after the last session (14 Hz) significantly decreased due to the WBVE and to the combined interventions (WBVE and AT). Briefly, putting together all these information, the effect of the (i) WBVE would be associated with the plasma concentrations of the inflammatory markers (63) (with action on the excitability of the peripheral nervous system) and the (ii) AT effect would related with the increase of the concentration of β-endorphins and can be blocked by naloxone.72

It is suggested that any type of exercise program performed regularly and monitored by healthcare professionals can improve pain, physical function and quality of life related to KOA in the short term.5 It was described that the performance, in functional tests and in all domains of the WOMAC, of KOA individuals improved due to the WBVE.66 Concerning to the effect of AT on the functionality, it was reported that AT in the elderly with lumbar back pain improves the disability level, pain and sensation, and functional activity.72 It was described that a combined intervention with exercise and AT group greater changes in the Oswestry Disability Questionnaire compared with the exercise-only group at the end of the 6-month follow-up period.79

All the considerations about the effects of the AT on the functionality of the KOA individuals, the clinical responses would be associated with mechanisms related to a close relationship with the autonomic nervous system, the neuroendocrine system, neuroimmunological factors, neuroinflammation, and neural reflex, as well as antioxidation.73,74 The effectiveness of using AT would be related to functional changes in the body, interconnected with neurological theory, the embryological theory, microsystems, the energy theory of Traditional Chinese Medicine and with hormonal basis.25,35,38 These biological responses might be considered in the cumulative effect on the HS of the combined intervention (WBVE and AT) in KOA individuals.

The current study contains some limitations that must be considered when interpreting the findings, such as the number and the heterogeneity of the participants. The association between the pathophysiology of KOA and the body’s response to the effects of WBVE needs to be further studied for a better understanding of these results. Several biomechanical parameters had been used in previous studies, and there is still no optimal protocol with respect to WBVE. Therefore, more works are needed to determine the dose of exercise (biomechanical parameters) needed to obtain the better functional improvements. Moreover, some other physiological parameters were not evaluated after the interventions. Furthermore, only three specific points in the ear were used in the AT, and only some frequencies of the mechanical vibration were used to generate WBVE.

In conclusion, despite of the limitations, it is possible to conclude that the HS was significantly improved in KOA individuals due to WBVE alone or combined with AT in a cumulative intervention. Moreover, the cited interventions did not impair HS of KOA individuals. In addition, the comfortable posture of the participants may be an incentive to perform a physical activity in this population in a safe way for knee joint.

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