NORDIC WALKING: A SYSTEMATIC REVIEW

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ABSTRACT
Nordic walking (NW) a new walking modality performed with poles as an aid to traction has been widely spread in recent years. Despite the many papers published many aspects are still unknown. So a systematic review has been done with the aim of presenting the state of the art and suggesting future research. Papers found were grouped in three categories: 31% were on body’s physiological response, 45%, were on fitness programs aimed at improving people’s health and 24% were on biomechanical aspects. It can be concluded conclude that NW can be considered an intermediate locomotive mode between walking and running. Oxygen consumption, heart rate, expiratory volume, energy expenditure and lactic acid levels are increased during NW at the same subjective speed as walking. There is no evidence of any contraindication in NW in the groups studied, and therefore it is an activity of great interest to most of the population. However, all is not yet elucidated and further research is needed.

Key Words: pole walk, exercise, health, biomechanics

RESUMEN
La Marcha Nórdica (MN), es nueva modalidad de caminar con bastones, cuya práctica en los últimos años se ha extendido ampliamente en la población. A pesar de los numerosos trabajos publicados, son muchos aspectos los todavía desconocidos. Por ello, se ha llevado a cabo una revisión sistemática con el objetivo de presentar las evidencias científicas desarrolladas y sugerir futuras líneas de investigación. Los documentos encontrados se agruparon en tres categorías: el 31% respecto a la respuesta fisiológica del organismo, el 45%, en programas de acondicionamiento físico para mejorar la salud, y el 24% respecto a aspectos biomecánicos. Se puede concluir que la MN es una modalidad de locomoción intermedia entre caminar y correr. El consumo de oxígeno, la frecuencia cardíaca, el volumen espiratorio, el gasto de energía y los niveles de ácido láctico se incrementan durante la MN a la misma velocidad que al caminar. No hay evidencia de ninguna contraindicación en la MN en los grupos estudiados, y por lo tanto es una actividad de gran interés para la mayoría de la población. Sin embargo, son necesarias más evidencias e investigación para confirmar las propiedades y beneficios de esta nueva modalidad de marcha.

Palabras clave: caminar con bastones, ejercicio, salud, biomecánica

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INTRODUCTION

Of an aerobic nature, walking is a physical activity which has been highly recommended in recent decades for its numerous benefits to the cardiovascular and skeletal muscle systems (Morris and Hardman, 1997). In recent years, a new walking modality called ‘Nordic walking’ (NW) has been widely spread. This activity is performed with walking poles as an aid to traction. In spite of being relatively recent, its international development has been considerable, partly due to the advantages this practice has been associated with.

The use of walking poles makes NW technique (Figure 1) different from that of the human gait. The person moves with his/her body slightly leaned forward, with contralateral hand-foot coordination so that the swing phase is always double, with one leg and with the pole of the opposite hand. This means that there are phases with two and four contact moments, which gives this walking style great stability.

The origins of NW are found in Scandinavia: in the 1930s, long-distance skiers began ‘ski-walking’ as off-season training during the summer (Schmidt, Helmkamp, Mack and Winski, 2006). As we know it today, NW dates back to the spring of 1997 (Schmidt et al., 2006), particularly with precursors Mauri Repo (1945-2002), a former coach of cross-country skiing in Finland, and Leena Jääskeläinen (1966), professor at the Faculty of Physical Education, University of Jyväskylä. In the 1990s, especially designed walking poles –known as "Sauvakävely" in Finnish– were developed for the activity. Finally, in 1997 the brand Exel® named this practice "NW", which is how it is commonly referred to at present. In 2000 Aki Karihtala founded the International Nordic Walking
Association (INWA), which developed specific educational programs and instructor training schemes, becoming a starting point for various associations, training courses, etc. all contributing to the expansion, dissemination and knowledge of NW worldwide.

As for the number of those who practise it (www.inwa-nordicwalking.com), about 10,000 regular participants were estimated in Finland, and in 2011 figures rose to nearly a million. Central Europe has seen a similar increase, the number of regular Nordic walkers being estimated at about 10 million people today.

Parallel to the boom in the number of participants, numerous articles started to be published, both for general dissemination purposes and at a scientific level, covering its biomechanical and physiological effects. However, many aspects are still unknown and even controversial concerning the implications of NW for the body. Therefore, the goal of this paper was to find and analyze published studies on NW with the aim of presenting the state of the art on the subject and suggesting avenues for future research.

**METHOD**

Papers were found in the most important on-line computer databases in the areas of Health and Physical Education:
- SportsDiscus (http://www.sirc.ca/products/sportsdiscus.cfm)
- Proquest (http://www.proquest.com/)
- ScienceDirect (http://www.sciencedirect.com/)
- SpringerLink (http://link.springer.com/)
- EBSCO (http://www2.ebsco.com/es-es/Pages/index.aspx)
- ISI web of knowledge (http://wokinfo.com/)
- Dialnet (http://dialnet.unirioja.es/)
- Google Scholar (http://scholar.google.es/)

The keywords used in the search were: "Nordic walking", "pole walk" and "pole striding."

The search was not limited by the year of publication.

After selecting all the studies that met the inclusion criteria, these were categorized into several groups according to the main variables of each study. The categories defined for this paper were: physiological aspects, biomechanical aspects and fitness programs.
RESULTS

Early studies focused on understanding the effects of practising NW on the body’s physiological response (Table 1). They account for 31% of the articles found. The results of these studies promoted another line of research focused on analyzing the practical application of Nordic walking in fitness programs aimed at improving people’s health and/or their implementation in rehabilitation programs (Table 2). These account for 45% of the papers found. Finally, the description of the biomechanical processes that occur during NW (Table 3), often compared to processes in normal human gait, account for 24% of the papers found (Figure 2).

FIGURE 2: Percentage of papers by category

DISCUSSION

The main findings in the three categories are described next.

Physiological aspects

Table 1 presents the list of the most relevant studies analyzing NW from this perspective, monitoring variables such as heart rate, oxygen consumption, energy expenditure, lactic acid concentration in blood, and respiratory volume.
### Table 1
Summary of physiological studies.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Study parameters:</th>
<th>Differences from walking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karawan et al.</td>
<td>1992</td>
<td>Muscular strength</td>
<td>40% increase</td>
</tr>
<tr>
<td>Hendrickson</td>
<td>1993</td>
<td>Oxygen consumption, heart rate and caloric expenditure</td>
<td>20% increase</td>
</tr>
<tr>
<td>Knox</td>
<td>1993</td>
<td>Effort perception</td>
<td>14% significant increase in NW</td>
</tr>
<tr>
<td>Rodgers et al.</td>
<td>1995</td>
<td>Oxygen consumption, Heart rate, Caloric expenditure, Effort perception</td>
<td>NW vs. Walking: 21 vs. 18 ml/kg/min; 133 vs. 122 ppm; 141 vs. 74 kcal; No change</td>
</tr>
<tr>
<td>Butts et al.</td>
<td>1995</td>
<td>Effort perception</td>
<td>Increase in physiological parameters, No change in effort perception</td>
</tr>
<tr>
<td>Porcari</td>
<td>1997</td>
<td>Oxygen consumption, Heart rate, Caloric expenditure, Effort perception</td>
<td>23% increase, 16% increase, 22% increase, 1.5 point significant increase</td>
</tr>
<tr>
<td>Anttila et al.</td>
<td>1999</td>
<td>Muscular activity (EMG)</td>
<td>Greater activity, reduced neck pain perception.</td>
</tr>
<tr>
<td>Jordan et al.</td>
<td>2001</td>
<td>Oxygen consumption, Heart rate</td>
<td>3.7 kcal/min increase, 34 ppm. increase</td>
</tr>
<tr>
<td>Morss et al.</td>
<td>2001</td>
<td>Oxygen consumption, Heart rate, Effort perception</td>
<td>20% increase, physiological parameters, No change in effort perception</td>
</tr>
<tr>
<td>Church et al.</td>
<td>2002</td>
<td>Oxygen consumption, Heart rate, Effort perception</td>
<td>20% increase, physiological parameters, No differences in effort perception</td>
</tr>
<tr>
<td>Ripatti</td>
<td>2002</td>
<td>Muscular strength</td>
<td>Significant increase</td>
</tr>
<tr>
<td>Gullstrand and Svedenhag</td>
<td>2003</td>
<td>VO2max, VE, lactic acid and heart rate</td>
<td>Significant increase</td>
</tr>
<tr>
<td>Höltke et al.</td>
<td>2003</td>
<td>VO2max, VE, lactic acid and heart rate</td>
<td>Significant increase</td>
</tr>
<tr>
<td>Aigner et al.</td>
<td>2004</td>
<td>Lactic acid and heart rate</td>
<td>Significant increase in untrained participants during NW</td>
</tr>
</tbody>
</table>
The vast majority of studies found statistically significant increases for oxygen consumption, heart rate and caloric expenditure during NW compared to normal walking (Aigner, Ledl-Kurkowski, Hörl and Salzmann, 2004; Butts et al., 1995; Church et al., 2002; Figard-Fabre et al., 2010; Hendrickson, 1993; Morss, Church, Earnest and Jordan, 2001; Porcari et al., 1997; Rodgers, VanHeest and...
Schachter, 1995) and differences in lactic acid levels (Gullstrand and Svedenhag, 2003; Höltke, Steuer, Schneider, Krakor and Jakob, 2003; Schiffer et al., 2006; Schiffer et al., 2011), especially in untrained participants (Aigner et al., 2004).

The influence of arm movement intensity on these physiological parameters was also explored, Jordan et al. (2001), showing that intense arm movement with poles increases the main physiological parameters compared to walking. Similarly, the study by Church et al. (2002) pointed out that the increase in oxygen consumption ranged between 5% and 63% depending on the intensity of arm movement and the technical performance of participants.

In the long term, the effects on the body of intervention programs based on the regular practice of NW (between 3 and 4 times a week for several months) (Anetttila, Jokinen and Holopainen, 1999; Figard-Fabre H. et al., 2010; Gullstrand and Svedenhag, 2003; Karawan et al., 1992; Ripatti, 2002) point to improvements in muscle strength of the upper limbs up to 40% and reductions in neck and shoulder pain.

Regarding subjective aspects such as the perception of the effort made or the mood, Church et al. (2002) argue that despite the increase in calorie consumption during NW, effort perception does not significantly increase. Furthermore, given the greater stability provided by the poles, the authors believe that NW can be a perfect activity for elderly people and for subjects with balance and/or stability problems while walking.

As a conclusion, oxygen consumption, heart rate, expiratory volume, energy expenditure and lactic acid levels are increased during NW at the same subjective speed as walking. This is considered to be one of the main benefits associated with NW and an argument for recommendation to special populations (elderly, obese, diabetic, etc.), as these groups often have difficulty in doing physical exercise on a regular basis. Their participation in an activity similar to walking but with greater benefits from the physiological viewpoint is very attractive.

**Biomechanical aspects**

Table 2 shows the published studies and the main results regarding biomechanical variables.
### TABLE 2
Summary of biomechanical studies.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Study parameters:</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunelle and Miller</td>
<td>1998</td>
<td>GRF</td>
<td>Higher GRF in vertical and antero-posterior components during NW.</td>
</tr>
<tr>
<td>Knight and Caldwell</td>
<td>2000</td>
<td>Kinematics when climbing with load</td>
<td>Longer step.</td>
</tr>
<tr>
<td>Willson et al.</td>
<td>2001</td>
<td>Kinematics and GRF</td>
<td>Longer step, longer contact time and GRF reduction.</td>
</tr>
<tr>
<td>Thorwesten et al.</td>
<td>2005</td>
<td>GRF</td>
<td>Higher GRF in vertical and antero-posterior components during NW.</td>
</tr>
<tr>
<td>Hagen et al.</td>
<td>2006</td>
<td>Goniometry, impacts, kinematics, GRF and inverse dynamics</td>
<td>Higher GRF in vertical and antero-posterior components during NW. Greater impact on wrists compared to walking.</td>
</tr>
<tr>
<td>Jöllenbeck et al.</td>
<td>2006</td>
<td>FRS</td>
<td>Higher GRF in vertical and antero-posterior components during NW.</td>
</tr>
<tr>
<td>Kleindienst et al.</td>
<td>2006</td>
<td>Kinematics and GRF</td>
<td>Higher GRF and braking impulse during NW. Lower GRF and impulse at take-off during NW.</td>
</tr>
<tr>
<td>Schwameder and Ring</td>
<td>2006</td>
<td>Kinematics, GRF and inverse dynamics</td>
<td>Reduction in joint load associated to participants' technique.</td>
</tr>
<tr>
<td>Thorwesten et al.</td>
<td>2006</td>
<td>GRF</td>
<td>Increased contact time in NW compared to normal walking.</td>
</tr>
<tr>
<td>Thorwesten et al.</td>
<td>2007</td>
<td>GRF</td>
<td>Increased contact time in NW compared to normal walking.</td>
</tr>
<tr>
<td>Kleindienst et al.</td>
<td>2007</td>
<td>Kinematics and GRF</td>
<td>GRF reduction at take-off during NW.</td>
</tr>
<tr>
<td>Koizumi et al.</td>
<td>2008</td>
<td>GRF and EMG</td>
<td>Reduced load on knee joint.</td>
</tr>
</tbody>
</table>
The first studies already showed differences between NW and normal human gait for a given walking speed: longer step (Knight and Caldewell, 2000; Shim, 2012; Stief et al., 2008; Willson et al., 2001), longer contact time (Thorwesten et al., 2005, 2006, 2007; Willson et al., 2001) and faster execution speed (Stief et al., 2008; Willson et al., 2001) as well as a reduction in step cadence (Knight and Caldewell, 2000).

Loads on the knee joint during NW and/or ground reaction forces are two of the variables that have drawn growing attention in recent years. The first papers showed lower loads on the knee joint during NW compared to walking (Willson et al. 2001; Koizumi et al., 2008). Furthermore, this reduction depended on the technical implementation: the higher the technical level, the lower the joint load (Schwameder and Ring, 2006).

Regarding ground reaction forces during initial landing, both the vertical component and the anterior-posterior one are higher during NW probably due to the increased speed and the longer step (Brunelle and Miller, 1998; Hagen et al., 2006 and 2011; Encarnación, 2012; Jensen et al., 2011; Kleindienst et al., 2006 and 2007; Stief et al., 2008; Thorwesten et al., 2005, 2006, 2007; Grüneberg et al., 2006; Jöllenbeck et al., 2006).

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**TABLE 2 (Cont.)**

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Methods</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stief et al.</td>
<td>2008</td>
<td>Kinematics, GRF and inverse dynamics</td>
<td>Longer step, GRF increase.</td>
</tr>
<tr>
<td>Pérez et al.</td>
<td>2009</td>
<td>Plantar pressures</td>
<td>Reduction in plantar pressures on metatarsals compared to walking.</td>
</tr>
<tr>
<td>Hagen et al.</td>
<td>2011</td>
<td>Goniometry, impacts, kinematics, GRF and inverse dynamics</td>
<td>Higher GRF in vertical and antero-posterior components during NW.</td>
</tr>
<tr>
<td>Pérez et al.</td>
<td>2011</td>
<td>Plantar pressures</td>
<td>Reduction in plantar pressures on metatarsals compared to walking, similar effect between beginners and experts. Residual effect of reduced pressures in experts during walking.</td>
</tr>
<tr>
<td>Encarnación</td>
<td>2012</td>
<td>Impacts, GRF, plantar pressures</td>
<td>Differences between normal walking and NW, effects of experience.</td>
</tr>
</tbody>
</table>

*GRF: ground reaction forces.
*EMG: electromyography, electrical activation.
During the swing phase of the foot, reductions in the vertical component of the ground reaction force and in plantar pressures are observed in the forefoot (Encarnación, 2012; Kleindienst et al., 2006 and 2007; Willson et al., 2001). This is probably due to the assistance of the pole that simultaneously pulls the contralateral foot.

Interestingly, the shock experienced by the musculoskeletal system during NW presents intermediate values between those of walking and running. Its possible effects on bone mineralization have not yet been addressed, while some studies suggest that impacts during walking are not sufficient so as to prevent the onset of osteoporosis, though they would be sufficient in running (Cavanaugh and Cann, 1988; Martyn and Carroll, 2008, 2009).

Finally, papers by Pérez et al. (2009 and 2011) show that, regardless of the level of practice, during NW plantar pressures in the central metatarsals are reduced by up to 40%. The authors also show that the regular practice of NW has a residual effect during walking, local pressures on the central metatarsals being significantly reduced. This has been interpreted as another beneficial effect associated with the regular practice of NW.

![Figure 3: Distribution of plantar pressures in experts and beginners under two speed conditions (Pérez et al., 2011).](image-url)
Fitness programs.

The use of NW programs to improve people's health, weight loss, and rehabilitation processes is based on the greater involvement of the upper limbs in relation to normal walking, and on the fact that it justifies the physiological and biomechanical changes described above. Localized studies are presented in Table 3.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Study variables / Pathology</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walter et al.</td>
<td>1996</td>
<td>Cardiac rehabilitation and vital capacity                                                   - Greater stimulus for vital and functional capacity improvement compared to walking.</td>
<td></td>
</tr>
<tr>
<td>Jacobson et al.</td>
<td>1997</td>
<td>Vestibular disorders, balance                                                               - Greater improvement compared to walking.</td>
<td></td>
</tr>
<tr>
<td>Baatile et al.</td>
<td>2000</td>
<td>Parkinson                                                                                    - General health improvement and improvement of everyday life activities.</td>
<td></td>
</tr>
<tr>
<td>Schiebel et al.</td>
<td>2003</td>
<td>Effectiveness in obese population                                                           - Higher than in walking.</td>
<td></td>
</tr>
<tr>
<td>Sprod et al.</td>
<td>2005</td>
<td>Breast cancer                                                                               - Improves upper limb musculature.</td>
<td></td>
</tr>
<tr>
<td>Wilk et al.</td>
<td>2005</td>
<td>Cardiac rehabilitation and vital capacity                                                   - Greater stimulus for vital and functional capacity improvement compared to walking.</td>
<td></td>
</tr>
<tr>
<td>Strömbeck et al.</td>
<td>2007</td>
<td>Sjögren's syndrome                                                                          - Improves symptoms compared to other programs.</td>
<td></td>
</tr>
<tr>
<td>Van Eijkeren et al.</td>
<td>2008</td>
<td>Parkinson                                                                                    - Significant improvement of mobility after training program.</td>
<td></td>
</tr>
<tr>
<td>Kocur et al.</td>
<td>2009a, 2009b</td>
<td>Cardiac rehabilitation and vital capacity                                 - Greater stimulus for vital and functional capacity improvement compared to walking.</td>
<td></td>
</tr>
<tr>
<td>Breyer et al.</td>
<td>2010</td>
<td>Chronic obstructive disease                                                                 - Longer movement times in comparison with control group.</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 3 (Cont.)

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Effectiveness</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figard-Fabre et al.</td>
<td>2010</td>
<td>Effectiveness in obese population</td>
<td>Higher than in walking.</td>
</tr>
<tr>
<td>Gram et al.</td>
<td>2010</td>
<td>Diabetes</td>
<td>No significant improvement of glycated haemoglobin.</td>
</tr>
<tr>
<td>Hartvigsen et al.</td>
<td>2010</td>
<td>Lower back ache</td>
<td>Symptoms improve, reduction in medication.</td>
</tr>
<tr>
<td>Morgulec-Adamowicz et al.</td>
<td>2011</td>
<td>Cardiac rehabilitation and vital capacity</td>
<td>Greater stimulus for vital and functional capacity improvement compared to walking.</td>
</tr>
<tr>
<td>Parkatti, et al.</td>
<td>2012</td>
<td>Strength, endurance and flexibility</td>
<td>Improvement of analyzed variables during NW compared to traditional fitness programs.</td>
</tr>
<tr>
<td>Figueiredo et al.</td>
<td>2013</td>
<td>Speed</td>
<td>106% increase compared to walking programs.</td>
</tr>
<tr>
<td>Keast et al.</td>
<td>2013</td>
<td>Cardiac rehabilitation and vital capacity</td>
<td>Greater stimulus for vital and functional capacity improvement compared to walking.</td>
</tr>
<tr>
<td>Takeshima et al.</td>
<td>2013</td>
<td>Strength, endurance and flexibility</td>
<td>Improvement of analyzed variables during NW compared to traditional fitness programs.</td>
</tr>
</tbody>
</table>

Programs targeted at the elderly have resulted in improvements in upper limb strength, cardiovascular endurance and flexibility compared to traditional fitness programs for the same population group (Parkatti, et al., 2012; Takeshima et al., 2013). NW has also been found to be 106% more effective in improving the speed in comparison with a traditional walking program (Figueiredo et al., 2013).

In cardiac rehabilitation programs, NW is a better stimulus in terms of cardiac rehabilitation and in improving the patients’ functional ability (Kocur, Deskur-Smielecka, Wilk and Dylewicz, 2009a, 2009b; Morgulec-Adamowicz, Marszałek and Jagustyn, 2011; Walter, Porcari, Brice and Terry, 1996; Wilk et al., 2005, Keast et al., 2013).

Equally positive results were found in training programs for an obese population (Figard-Fabre H. et al., 2010; Schiebel et al., 2003), in patients with vestibular disorders (Jacobson et al., 1997), in patients with chronic lower back ache (Hartvigsen, Morse, Bendix and Manniche, 2010) in subjects suffering from claudication as a consequence of peripheral arterial disease (Collins et al., 2005; Oakley et al., 2008), patients with Sjögren's syndrome, associated with rheumatism (Strömbeck, Theander and Jacobsson, 2007), in individuals with
Parkinson’s disease (Baatile, Langbein, Weaver, Maloney and Jost, 2000; Van Eijkeren et al., 2008), in depressed patients (Suija et al., 2009), in breast cancer patients (Sprod, Drum, Bentz, Carter and Schneider, 2005), in patients with chronic obstructive pulmonary disease (Breyer et al., 2010).

However, not all results have been positive. Allet et al. (2009) suggest that patients who had suffered hemiparesis perceived NW to be less comfortable compared with a four-way support walking frame or a simple stick. Similarly, Gram, Christensen, Christiansen and Gram (2010) applied an intervention program based on the regular practice of NW to a diabetic population. After the training period, all groups improved in terms of weight loss but no significant improvement was found in glycated hemoglobin (HbA1c), which suggests that evidences do not support the role of NW as beneficial stimulation from the physiological point of view in patients with type 2 diabetes, although no contraindications in this respect have been proved with such populations either.

CONCLUSIONS

In light of the results presented, one can conclude that NW is distinctly different from walking: it is more stable, and higher speeds can be reached with greater physiological demands but without increasing the subjective effort perception. Therefore, it can be considered an intermediate mode between normal walking and running.

These features have contributed to its increasing popularity, being perceived as an activity with high potential to improve fitness and health, especially in populations with impaired mobility. This is proved by numerous studies comparing the effects of NW in programs aimed at improving the health of different populations.

At biomechanical level, NW, if compared to normal walking, shows an increase in the rate of displacement due to the longer stride, with a much larger movement of the upper limbs. Muscular activity is also increased, especially in the upper limbs. Ground reaction forces are also higher, while a reduction in plantar pressures is found in the central metatarsals.

We can conclude that to date there is no evidence of any contraindication in NW in the groups studied, and therefore it is an activity of great interest to most of the population. However, all is not yet elucidated and further research should be conducted with the following goals:

- To determine its effects on different structural and functional systems of the organism in the long term, especially on bone mineralization, since running has a positive effect but not walking; NW can be considered a transition between them.
- To analyze the effect of different types of footwear (unstable, minimalist, etc.) on plantar pressure, since to date all studies have been performed with standard sports shoes.
- To analyze muscular activity in different muscle groups of both the lower limbs and the spine, as most studies completed so far with EMG have focused on the muscles of the upper limbs.

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compared to walking. *European journal of applied physiology, 111*(6), 1121-1126.


