European Journal of Human Movement, 2014: **33**, 26-45

NORDIC WALKING: A SYSTEMATIC REVIEW

Pedro Pérez-Soriano [1]; Alberto Encarnación-Martínez [2]; Inmaculada Aparicio-Aparicio [1]; José Vicente Giménez [1]; Salvador Llana-Belloch [1]

1. Research Group on Biomechanics Applied to Sport (GIBD). Department of Physical and Sports Education. University of Valencia, Spain.
2. Research Group on Health, Physical Activity, Fitness and Motor Behavior (GISAFFCOM). Catholic University of Murcia, Spain.

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 de 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

---

Correspondence:
Pedro Pérez-Soriano
Research Group on Biomechanics Applied to Sport (GIBD).
Department of Physical and Sports Education.
University of Valencia.
C/ José Gascó y Oliag, 3
46010 - Valencia
pedro.perez-soriano@uv.es

Submitted: 05/09/2014
Accepted: 25/11/2014

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.

A: The right heel and the left pole make contact with the ground. The left foot and the right pole are swinging.

B: The left foot and the right pole finish swinging, while the opposite limbs are already fully planted.

C: The right foot and the left pole are in swing phase. The left foot and the right pole are about to contact the ground.

D: The left heel and the right pole make contact with the ground. The right foot and the left pole finish the swing.

FIGURE 1: Photographic series of a Nordic Walking step

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:

- PubMed (http://www.ncbi.nlm.nih.gov/pubmed)
- 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).

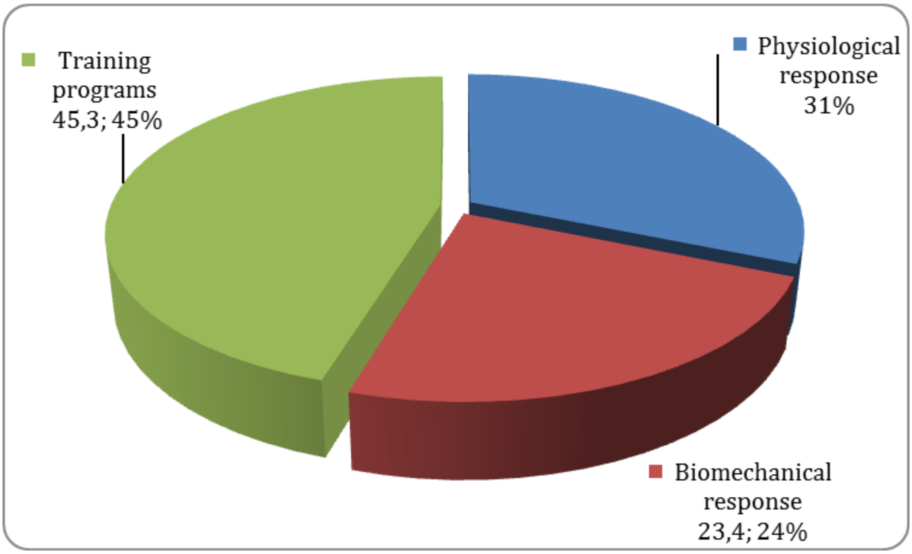

FIGURE 2: Percentage of papers by category

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.

Author	Year	Study parameters:	Differences from walking
Karawan et al.	1992	- Muscular strength	- 40% increase
Hendrickson	1993	- Oxygen consumption, heart rate and caloric expenditure	- 20% increase
Knox	1993	- Effort perception	- 14% significant increase in NW
Rodgers et al.	1995	- Oxygen consumption - Heart rate - Caloric expenditure - Effort perception	NW vs. Walking: - 21 vs. 18 ml/kg/min; - 133 vs. 122 ppm; - 141 vs. 74 kcal - No change
Butts et al.	1995	- Effort perception	- Increase in physiological parameters - No change in effort perception
Porcari	1997	- Oxygen consumption - Heart rate - Caloric expenditure - Effort perception	- 23% increase - 16% increase - 22% increase - 1.5 point significant increase
Anttila et al.	1999	- Muscular activity (EMG)	- Greater activity, reduced neck pain perception.
Jordan et al.	2001	- Oxygen consumption - Heart rate	- 3.7 kcal/min increase - 34 ppm. increase
Morss et al.	2001	- Oxygen consumption - Heart rate - Effort perception	- 20% increase, physiological parameters - No change in effort perception
Church et al.	2002	- Oxygen consumption - Heart rate - Effort perception	- 20% increase, physiological parameters - No differences in effort perception
Ripatti	2002	- Muscular strength	- Significant increase
Gullstrand and Svedenhag	2003	- VO2max, VE, lactic acid and heart rate	- Significant increase
Höltke et al.	2003	- VO2max, VE, lactic acid and heart rate	- Significant increase
Aigner et al.	2004	- Lactic acid and heart rate	- Significant increase in untrained participants during NW

TABLE 1 (Cont.)

Hagner et al.	2009	- HDL - LDL - Triglycerides - BMI	- No comparison with normal walking. NW intervention in 168 subjects. - HDL ↑; LDL ↓; Triglycerides ↓; BMI ↓
Schiffer et al.	2006, 2009	- Heart rate - Lactic acid - Relative VO2 - Effort perception	- Compares walking, running and NW. - Lac increases in NW in all test stages. - With 1.8m/s increase 8% relative VO2.
Schiffer et al.	2011	- Heart rate - Lactic acid - Relative VO2 - Effort perception - EMG biceps, triceps, trapezius and deltoids	- Different pole weights (normal walking, NW, NW+0.5 kg, NW +1.0 kg, NW +1.5 kg) - ↑ activation biceps brachii with ↑ weight. No dif. on trapezius, deltoids and biceps. - RVO2 ↑ in NW than in normal walking (no weight dif in poles) - Lactate ↑ in NW than in normal walking (no weight dif in poles)
Sugiyama	2013	- iEMG - VO2 - Effort perception OMNI - Heart rate	- In NW, lower limb muscular activity is reduced during planting phases. - Increased energy expenditure of upper limbs at different speeds.
Shim et al.	2012, 2013	- EMG upper and lower limbs	- No differences between subjects using poles in comparison with walking in lower limb muscular activity. - Pole use increases upper limb muscular activity compared to normal walking.
Tschentscher et al.	2013	- Review paper	- NW favours a reduction in heart rate at rest, blood pressure, the ability to exercise, oxygen consumption, and quality of life. - NW recommended as a prevention physical activity.

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) (Anettila, 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.

Author	Year	Study parameters:	
Jacobson et al.	1997	- Kinematics, balance	- Improved stability in individuals with vestibular system disorders.
Brunelle and Miller	1998	- GRF	- Higher GRF in vertical and antero-posterior components during NW.
Knight and Caldewell	2000	- Kinematics when climbing with load	- Longer step.
Willson et al.	2001	- Kinematics and GRF	- Longer step, longer contact time and GRF reduction.
Thorwesten et al.	2005	- GRF	- Higher GRF in vertical and antero-posterior components during NW.
Hagen et al.	2006	- Goniometry, impacts, kinematics, GRF and inverse dynamics	- Higher GRF in vertical and antero-posterior components during NW. Greater impact on wrists compared to walking.
Jöllenbeck et al.	2006	- FRS	- Higher GRF in vertical and antero-posterior components during NW.
Kleindienst et al.	2006	- Kinematics and GRF	- Higher GRF and braking impulse during NW. Lower GRF and impulse at take-off during NW.
Schwameder and Ring	2006	- Kinematics, GRF and inverse dynamics	- Reduction in joint load associated to participants' technique.
Thorwesten et al.	2006	- GRF	- Increased contact time in NW compared to normal walking.
Thorwesten et al.	2007	- GRF	- Increased contact time in NW compared to normal walking.
Kleindienst et al.	2007	- Kinematics and GRF	- GRF reduction at take-off during NW.
Koizumi et al.	2008	- GRF and EMG	- Reduced load on knee joint.

TABLE 2 (Cont.)

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

**GRF: ground reaction forces.*
**EMG: electromyography, electrical activation.*

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).

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.

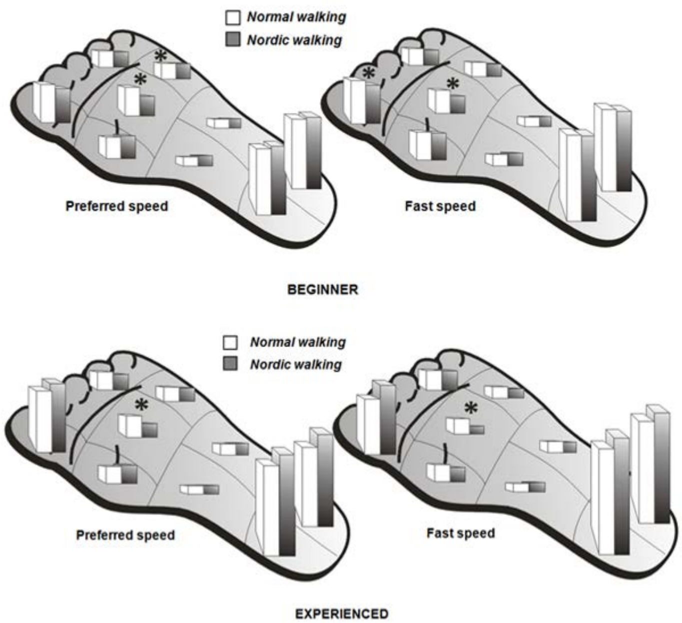

FIGURE 3: Distribution of plantar pressures in experts and beginners under two speed conditions (Pérez et al., 2011).

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 3
Summary of fitness studies.

Author	Year	Study variables / Pathology	Differences
Walter et al.	1996	- Cardiac rehabilitation and vital capacity	- Greater stimulus for vital and functional capacity improvement compared to walking.
Jacobson et al.	1997	- Vestibular disorders, balance	- Greater improvement compared to walking.
Baatile et al.	2000	- Parkinson	- General health improvement and improvement of everyday life activities.
Schiebel et al.	2003	- Effectiveness in obese population	- Higher than in walking.
Sprod et al.	2005	- Breast cancer	- Improves upper limb musculature.
Wilk et al.	2005	- Cardiac rehabilitation and vital capacity	- Greater stimulus for vital and functional capacity improvement compared to walking.
Strömbeck et al.	2007	- Sjögren's syndrome	- Improves symptoms compared to other programs.
Van Eijkeren et al.	2008	- Parkinson	- Significant improvement of mobility after training program.
Allet et al.	2009	- Hemiparesis	- Comfort not improved with poles.
Kocur et al.	2009a, 2009b	- Cardiac rehabilitation and vital capacity	- Greater stimulus for vital and functional capacity improvement compared to walking.
Suija et al.	2009	- Depressed subjects	- Reduction in medication.
Breyer et al.	2010	- Chronic obstructive disease	- Longer movement times in comparison with control group.

TABLE 3 (Cont.)

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

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, Morsə, 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.

REFERENCES

Aigner, A., Ledl-Kurkowski, E., Hörl, S., y Salzmann, K. (2004). Effekte von nordic walking bzw. normalem gehen auf herzfrequenz und arterielle laktatkonzentration. *Österreichisches Journal für Sportmedizin, 14(3),* 32-36.

Allet, L., Leemann, B., Guyen, E., Murphy, L., Monnin, D., Herrmann, F.R. y cols., (2009). Effect of different walking aids on walking capacity of patients with poststroke hemiparesis. *Archives of Physical Medicine and Rehabilitation, 90(8),* 1408-1413. DOI: 10.1016/j.apmr.2009.02.010.

Anttila, R., Holopainen S., y Jokinen. (1999). *Pole walking and the effect of regular 12-week pole walking exercise on neck and shoulder symptoms: The mobility of the cervical and thoracic spine and aerobic capacity.* Trabajo final de carrera. Helsinki IV College for Health Care Professionals.

Baatile, J., Langbein, W.E., Weaver, F., Maloney, C., y Jost, M.B. (2000). Effect of exercise on perceived quality of life of individuals with Parkinson's disease. *Journal of Rehabilitation Research & Development, 37(5)*, 529-534.

Breyer, M.K., Breyer-Kohansal, R., Funk, G.C., Dornhofer, N., Spruit, M.A., Wouters, E.F., Burghuber, O.C., y Hartl, S. (2010). Nordic Walking improves daily physical activities in COPD: a randomised controlled trial. *Respiratory Research, 22*, 111:112.

Brunelle, E.A., y Miller, M.K. (1998). The effects of walking poles on ground reaction forces. *Research Quarterly for Exercise and Sports, 69(Suppl.)*, A30.

Butts, N.K., Knox, K.M., y Foley, T.S. (1995). Energy cost of walking on a dual-action treadmill in men and women. *Medicine and Science in Sports and Exercise, 27(1),* 121-125.

Cavanaugh, D.J., y Cann, C.E. (1988). Brisk walking does not stop bone loss in postmenopausal women. *Bone*,9, 201–204.

Church, T. S., Earnest, C. P., & Morss, G. M. (2002). Field testing of physiological responses associated with Nordic walking. *Research Quarterly for Exercise & Sport. 73(3)*, 296-300.

Collins, E.G., Langbein, W.E., Orebaugh, C., Bammert, C., Hanson, K., Reda, D., Edwads, L.C., y Littooy, F.N. (2005). Cardiovascular training effect associated with polestriding exercise in patients with peripheral arterial disease. *Journal of Cardiovascular Nursing, 20(3),* 177-185.

Encarnación, A. (2012). *Análisis biomecánico de la marcha Nórdica: efectos de la experiencia y de la velocidad de práctica sobre el patrón de presión plantar, las fuerzas de reacción del suelo y los niveles de impacto.* Tesis Doctoral, Universidad de Valencia.

Figard-Fabre, H., Fabre, N., Leonardi, A., y Schena, F. (2010). Physiological and perceptual responses to Nordic walking in obese middle-aged women in comparison with the normal walk. *European Journal of Applied Physiology, 108(6),* 1141-1151.

Figueiredo, S., Finch, L., Mai, J., Ahmed, S., Huang, A., & Mayo, N. E. (2013). Nordic walking for geriatric rehabilitation: a randomized pilot trial. *Disability and Rehabilitation, 35(12),* 968-975.

Fritschi, J. O., Brown, W. J., Laukkanen, R., & van Uffelen, J. G. Z. (2012). The effects of pole walking on health in adults: A systematic review. *Scandinavian Journal of Medicine & Science in Sports, 22(*5), 70-78

Fritz, T., Caidahl, K., Krook, A., Lundstrom, P., Mashili, F., Osler, M., Szekeres, F. L. M., Ostenson, C. G., Wandell, P., & Zierath, J. R. (2013). Effects of Nordic walking on cardiovascular risk factors in overweight individuals with type 2 diabetes, impaired or normal glucose tolerance. *Diabetes-Metabolism Research and Reviews, 29(1),* 25-32.

Gram, B., Christensen, R., Christiansen, C., y Gram, J. (2010). Effects of nordic walking and exercise in type 2 diabetes mellitus: A randomized controlled trial. *Clinical Journal of Sport Medicine, 20(5),* 355-361.

Grüneberg, C., Jöllenbeck, T., Leyser, D., Mull, M., y Classen, C. (2006). Field testing to determine biomechanical loading of the lower limb during nordic walking versus walking-Comparison between Nordic walking instructors and experienced nordic walkers. *Journal of Biomechanics, 39, (Suppl.1)*, S186.

Gullstrand, L., y Svedenhag, J. (2003). Training effects after 7 weeks of pole- and normal walking. En E. Mueller, H. Schwameder, G. Zallinger y V. Fastenbauer (Eds.), *Book of Abstracts of 8th Annual Congress of the European College of Sport Science,* (pp. 33-34). Salzburg, Austria: International Society of Biomechanics in Sports.

Hagen, M., Henning, E.M., y Stieldorf, P. (2006). Ground Reaction Forces, rearfoot motion and wrist acceleration in Nordic Walking. En H. Schwamader, G. Strutzenberger, V. Fastenbauer, S Lindinger, y E. Müller (Eds.), *Proceedings of the XXIV International Symposium on Biomechanics in Sports* (pp.139-142). Salzburg, Austria: International Society of Biomechanics in Sports.

Hagen, M., Henning, E.M., y Stieldorf, P. (2011). Lower and upper extremity loading in nordic walking in comparison with walking and running. *Journal of Applied Biomechanics, 27*, 22-31.

Hagner, W., Hagner-Derengowska, M., Wiacek, M., y Zubrzycki. I. Z. (2009). Changes in level of VO2max, blood lipids, and waist circumference in the response to moderate endurance training as a function of ovarian aging. *Menopause, 16(5),* 1009-1013.

Hansen, L., Henriksen, M., Larsen, P., & Alkjaer, T. (2008). Nordic Walking does not reduce the loading of the knee joint. *Scandinavian Journal of Medicine & Science in Sports, 18(4),* 436–441.

Hartvigsen, J., Morsø, L., Bendix, T., y Manniche, C. (2010). Supervised and non-supervised Nordic walking in the treatment of chronic low back pain: a single blind randomized clinical trial. *BMC Musculoskeletal Disorders, 11*, 30.

Hendrickson, T.L. (1993). *The physiological responses to walking with and without Power Poles™ on treadmill exercise*. Tesis Doctoral, University of Wisconsin, La Grosse.

Höltke, V., Steuer, M., Schneider, U., Krakor, S., y Jakob E. (2003). Walking vs. Nordic-walking. Comparison of strain. *Deutstche Zeitschrift Für Sportmedizin, 54*, S81.

Jacobson, B.H., Caldwell, B., y Kulling, F.A. (1997). Comparison of hiking stick use on lateral stability while balancing with and without a load. *Perceptual and Motor Skills, 85(1),* 347-350.

Jensen, S. B., Henriksen, M., Aaboe, J., Hansen, L. Simonsen, E. B., & Alkjaer, T. (2011). Is it possible to reduce the knee joint compression force during level walking with hiking poles? *Scandinavian Journal of Medicine & Science in Sports, 21(6),* E195-E200.

Jöllenbeck, T., Grüneberg, C., Leyser, D., Mull, M., y Classen, C. (2006). Nordic walking versus walking - field testing to determine biomechanical loading of the lower limb. *Journal of Biomechanics, 39(Suppl.1),* S185.

Jordan, A.N., Olson, T.P., Earnest, C.P., Morss, G.M., y Church, T.S. (2001). Metabolic cost of high intensity poling while Nordic Walking versus normal walking. *Medicine and Science in Sports and Exercise, 33(5),* S86.

Karawan, A., Porcari, J.P., Butts, N.K., Postmus, A.M., Stoughton, L., y Larkin, J. (1992). Effects of 12 weeks of walking or exerstriding on upper body strength and endurance. *Medicine and Science in Sports and Exercise, 24(5)*, S824.

Keast, M. L., D'Angelo, M. E. S., Nelson, C. R. M., Turcotte, S. E., McDonnell, L. A., Nadler, R. E., Reed, J. L., Pipe, A. L., & Reid, R. D. (2013). Randomized Trial of Nordic Walking in Patients With Moderate to Severe Heart Failure. *Canadian Journal of Cardiology, 29(11),* 1470-1476.

Kleindienst, F.I., Michel, K.J., Schwarz, J., y Krabbe, B. (2006). [Comparison of kinematic and kinetic parameters between the locomotion patterns in nordic walking, walking and running]. [Artículo en Alemán]. *Sportverletzung Sportschaden, 20(1),* 25-30.

Kleindienst, F.I., Michel, K.J., Stief, F., Wedel, F. Campe, S., y Krabbe, B. (2007). [Comparison of joint loading of lower extremities between the locomotion patterns nordic walking, walking and running using inverse dynamics] [Artículo en Alemán]. *Deutsche Zeitschrift für Sportmedizin, 58(4),* 105-111.

Knight, C.A., y Caldwell, G.E. (2000). Muscular and metabolic costs of uphill backpacking: are hinking poles benefical? *Medicine and Science in Sports and Exercise, 32,* 2093-2101.

Knobloch, K., y Vogt, P.M. (2006). Nordic pole walking injuries nordic walking thumb as novel injury entity. *Sportverletz Sportschaden, 20(3),*137-142.

Knox, K.M. (1993). *Energy cost of walking with and without arm activity on the Cross Walk dual motion cross trainer.* Tesis Doctoral, University of Wisconsin-La Grosse.

Kocur, P., Deskur-Smielecka, E., Wilk, M., y Dylewicz P. (2009b). Estimation of energy expenditure during various forms of exercise training in early cardiac rehabilitation. *Physiotherapy, 17(2)*, 3-11.

Kocur, P., Deskur-Smielecka, E., Wilk, M., y Dylewicz, P. (2009a). Effects of Nordic Walking training on exercise capacity and fitness in men participating in early, short-term inpatient cardiac rehabilitation after an acute coronary syndrome - a controlled trial. *Clinical Rehabilitation, 23(11)*, 995-1004.

Koizumi, T., Tsujiuchi, N., Takeda, M., y Murodate, Y. (2008). Physical Motion Analysis of Nordic Walking. En: M. Estivalet, y P. Brisson, (Eds.), *The Engineering of Sports 7(Vol.2)* (pp. 379-385). Paris: Springer Verlag France.

Kukkonen-Harjula, K., Hiilloskorpi, H., Manttari, A., Pasanen, M., Parkkari, J., Suni, J., Fogelholm, M., y Laukkanen, R. (2007). Selfguided brisk walking training with or without poles: a randomized- controlled trial in middle-aged women. *Scandinavian Journal Medicine Science Sports,* 17, 316–323.

Kukkonen-Harjula, K., Hiilloskorpi, H., Manttari, A., Pasanen, M., Parkkari, J., Suni, J., Fogelholm, M., y Laukkanen, R. (2007). Selfguided brisk walking training with or without poles: a randomized- controlled trial in middle-aged women. *Scandinavian Journal Medicine Science Sports,* 17, 316–323.

Martyn-St, J.M. y Carroll S. (2008). Meta-analysis of walking for preservation of bone mineral density in postmenopausal women. *Bone.* 43(3), 521-531.

Martyn-St, J. M. y Carroll, S. (2009). A meta-analysis of impact exercise on postmenopausal bone loss: the case for mixed loading exercise programmes. *British Journal of Sports Medicine,*43, 898-908.

Morgulec-Adamowicz, N., Marszałek, J., y Jagustyn, P. (2011). Nordic Walking as an adapted physical activity. *Human Movement, 12(2)*, 124-132.

Morris, J. N., y Hardman, A. (1997Walking to health. *Sports Medicine, 23*, 306-332.

Morss, G. M., Church, T. S., Earnest, C. P., y Jordan, A. N. (2001). Field test comparing the metabolic cost of normal walking versus Nordic walking. *Medicine and Science in Sports and Exercise, 33(5),* S23.

Oakley, C., Zwierska, I., Tew, G., Beard, J.D., y Saxton, J. M. (2008). Nordic poles immediately improve walking distance in patients with intermittent claudication. European *Journal of Vascular and Endovascular Surgery, 36(6),* 689–694.

Parkatti, T., Perttunen, J., & Wacker, P. (2012). Improvements in Functional Capacity From Nordic Walking: A Randomized Controlled Trial Among Older Adults. *Journal of Aging and Physical Activity*, *20(1)*, 93-105.

Pérez, P., Llana, S., Encarnación, A., y Fuster, M. A. (2009). Marcha Nórdica: actividad física alternativa en el cuidado del pie. *Motricidad. European Journal of Human Movement, 22*, 83-94.

Pérez, P., Llana, S., Martínez-Nova, A., Morey, G., y Encarnación, A. (2011). Nordic walking practice might improve plantar pressure distribution. *Research Quarterly for Exercise and Sport, 82 (4),* 593-599.

Perrey, S., y Fabre, N. (2008). Exertion during uphill, level and downhill walking with and without hiking poles. *Journal of Sports Science and Medicine, 7,* 32-38.

Porcari, J. P., Hendrickson, T. L., Walter, P. R., Terry, L., & Walsko, G. (1997). The physiological responses to walking with and without Power Poles on treadmill exercise. *Research Quarterly for Exercise & Sport, 68(2)*, 161-166.

Ripatti, T. (2002). Effect of nordic walking training program on cardiovascular fitness. Sportartspezifische Leistungsfähigkeit, Deutsche Sporthochschule Köln, Germany.

Rodgers, C. D., VanHeest, J. L., & Schachter, C. L. (1995). Energy expenditure during submaximal walking with exerstriders. *Medicine & Science in Sports & Exercise, 27(4)*, 607-611.

Sánchez, J. (1999). *Biomecánica de la Marcha Humana Normal y Patológica*. Valencia: Instituto de Biomecánica de Valencia.

Schiebel, F., Heitkamp, H. C., Thoma, S., Hipp, A., y Horstmann, T. (2003). Nordic walking and walking in comparison. *Deutstche Zeitschrift Für Sportmedizin, 54*, S.43.

Schiffer, T., Knicker, A., Dannohl, R., y Struder, H. K. (2009). Energy cost and pole forces during nordic walking under different surface conditions. *Medicine and Science in Sports and Exercise, 41*(3), 663-668.

Schiffer, T., Knicker, A., Hoffman, U., Harwig, B., Hollmann, W., y Strüder, H. K. (2006). Physiological responses to Nordic walking, walking and jogging. *European Journal of Applied Physiology, 98(1),* 56–61.

Schiffer, T., Knicker, A., Montanarella, M., & Strüder, H. K. (2011). Mechanical and physiological effects of varying pole weights during Nordic walking compared to walking. *European journal of applied physiology*, *111*(6), 1121-1126.

Schmidt, M., Helmkamp, A., Mack, N., y Winski, N. (2006). *Entrenamiento para todo el cuerpo: Practicando el Nordic Walking.* Ed. Edimat Libros, Madrid.

Schwameder, H., y Ring, S. (2006). Knee joint loading and metabolic energy demand in walking, nordic walking and running. *Journal of Biomechanics, 39(Suppl.1),* S185.

Shim, J. M. (2012). Comparison of Gait and Feet during Nordic Pole Walking and Unassisted Walking on a Treadmill *Journal of Physical Therapy Science, 24(12),* 1225-1228.

Shim, J. M., Kwon, H. Y., Kim, H. R., Kim, B. I., y Jung, J. H. (2013). Comparison of the Effects of Walking with and without Nordic Pole on Upper Extremity and Lower Extremity Muscle Activation. *Journal of Physical Therapy Science, 25(12),* 1553-1556.

Sprod, L. K., Drum, S. N., Bentz, A. T., Carter, S. D., y Schneider, C. M. (2005). The effects of walking poles on shoulder function in breast cancer survivors. *Integrative Cancer Therapies. 4(4),* 287-293.

Stief, F., Kleindienst, F. I., Wiemeyer, J., Wedel, F., Campe, S., y Krabbe, B. (2008). Inverse dynamic analysis of the lower extremities during nordic walking, walking, and running. *Journal of Applied Biomechanics, 24(4),* 351–359.

Strömbeck, B. E., Theander, E., y Jacobsson L. T. H. (2007). Effects of exercise on aerobic capacity and fatigue in women with primary Sjögren's syndrome. *Rheumatology 46(5),* 868-871.

Sugiyama, K., Kawamura, M., Tomita, H., & Katamoto, S. (2013). Oxygen uptake, heart rate, perceived exertion, and integrated electromyogram of the lower and upper extremities during level and Nordic walking on a treadmill. *Journal of Physiological Anthropology, 32*-2. DOI: 10.1186/1880-6805-32-2

Suija, K., Pechter, U., Kalda, R., Tähepõld, H., Maaroos, J., y Maaroos, H. I. (2009). Physical activity of depressed patients and their motivation to exercise: Nordic Walking in family practice. *International Journal of Rehabilitation Research, 32(2),* 132-138.

Takeshima, N., Islam, M. M., Rogers, M. E., Rogers, N. L., Sengoku, N., Koizumi, D., Kitabayashi, Y., Imai, A., & Naruse, A. (2013). Effects of Nordic Walking compared to Conventional Walking and Band-Based Resistance Exercise on Fitness in Older Adults. *Journal of Sports Science and Medicine, 12(3),* 422-430.

Thorwesten, L., Overhaus, N., Rudack, P., y Völker, K. (2005). Vergleichende plantare Druckverteilungsmessung beim Nordic Walking und Walking. *Deutsche Zeitschrift fur Sportmedizin, 56(7/8)*, 215.

Thorwesten, L., Overhaus, N., y Völker, K. (2006). Ground reaction forces in nordic Walking and Walking. En H. Schwamader, G. Strutzenberger, V. Fastenbauer, S Lindinger, y E. Müller (Eds.), *Proceedings of the XXIV International Symposium on Biomechanics in Sports* (p. 628). Salzburg, Austria: International Society of Biomechanics in Sports.

Thorwesten, L., Overhaus, N., y Völker, K. (2007). Vertical ground reaction forces in nordic walking and walking. En *Proceedings 12th Annual Congress of the European College of Sport Science (ECSS*), Jyväskylä, Finland.

Tschentscher, M., Niederseer, D., & Niebauer, J. (2013). Health Benefits of Nordic Walking A Systematic Review. *American Journal of Preventive Medicine, 44(1),* 76-84.

Van Eijkeren, F. J., Reijmers, R. S., Kleinveld, M. J., Minten, A., Bruggen, J. P., y Bloem, B. R. (2008). Nordic walking improves mobility in Parkinson's disease. *Movement Disorders, 23(15)*, 2239-2243.

Walter, P. R., Porcari, J. P., Brice G., y Terry L. (1996). Acute responses to using walking poles in patients with coronary artery disease. *Journal of Cardiopulmonary Rehabilitation, 16*, 245-250.

Wilk, M., Kocur, P., Różańska, A., Przywarska, I., Dylewicz, P., y Owczarski, T. (2005). Assessment of the selected physiological effects of Nordic Walking performed as a part of a physical exercise program during the second phase of rehabilitation after a myocardial infarction [en Polaco]. *Rehabilitacja Medyczna, 9(2),* 33–39.

Willson, J., Torry, M. R., Decker, M. J., Kernozek, T., y Streadman, J. R. (2001). Effects of walking poles on lower extremity gait mechanics*. Medicine and Science in Sports and Exercise, 33(1), 142–147.*