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ORIGINAL PAPER

NORDIC WALKING TRAINING VERSUS REHABILITATION PROGRAMME IN IMPROVING GAIT IN ADULT PERSONS WITH DOWN SYNDROME

PORÓWNANIE WPŁYWU TRENINGU NORDIC WALKING I REHABILITACJI RUCHOWEJ NA PARAMETRY CHODU U OSÓB Z ZESPOŁEM DOWNA

Agnieszka Skiba[1], Iwona Sulowska[1], Szymon Podsiadło[1], Paulina Aleksander-Szymanowicz[1], Amadeusz Skiba[1], Jakub Marchewka[1], Wiesław Chwała[2], Anna Marchewka[1]
[1]Department of Clinical Rehabilitation
University of Physical Education in Cracow, Poland
[2]Department of Biomechanics
University of Physical Education in Cracow, Poland

ABSTRACT

Introduction

Subjects with DS show a dysfunction of gait expressed by different values of the spatiotemporal parameters of gait compared to the physiological norm.

It is known that exercises and various activities have positive effect on balance and gait, but there is only a few scientific evidences concerning above mentioned in people with DS.

Aim

The aim of the study was to assess the spatiotemporal parameters of adult persons with DS following regular Nordic Walking training and rehabilitation programme and in a group that did not undergo training during the intervention period.

Material and methods

The study involved 32 adults with DS, aged 25–40 years, in Cracow. Participants were randomly divided into three groups: NW Group, which underwent a 10-week Nordic Walking training programme; the group, which attended rehabilitation programme (RP) over 10 weeks or the C Group, the control group. Subjects were examined twice: 1 week before training and a week immediately after intervention. Gait was evaluated by the Vicon 250.

Results

After the training, statistically significant changes were observed in many of the spatio parameters in the NW group, i.e. step length and cycle length increased and in some kinematic parameters in both of the experimental groups. The walk ratio was statistically different between NW and RP and also between NW and C after the 10-week programme.

Conclusions

NW training is better method of improving spatiotemporal parameters in persons with DS than rehabilitation programme. NW training programme is effective and should be included as a part of daily training of persons with DS.

Author responsible for correspondence:
Agnieszka Skiba
Department of Clinical Rehabilitation
University of Physical Education in Krakow
Al. Jana Pawla II 78
31-571 Krakow, Poland
agnieszka.skiba@awf.krakow.pl

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STRESZCZENIE

Wstęp

Osoby z zespołem Downa (ZD) wykazują dysfunkcję chodu wyrażoną odmiennymi wartościami parametrów czasowo przestrzennych w porównaniu z normą fizjologiczną. Niewiele jest doniesień na temat wpływu różnych form aktywności fizycznej na chód osób z ZD z wykorzystaniem obiektywnych metod diagnostycznych.

Cel pracy

Celem badań była ocena i porównanie wpływu treningu Nordic Walking i rehabilitacji ruchowej na chód u osób dorosłych z zespołem Downa.

Materiał i metody

Grupę badaną stanowiły 32 osoby dorosłe z zespołem Downa w wieku 25–40 lat. Badanych zakwalifikowano losowo do 3 grup: grupy poddanej treningowi Nordic Walking (NW), grupy biorącej udział w programie rehabilitacji ruchowej oraz do grupy kontrolnej. Zakwalifikowane osoby zbadano dwukrotnie: w tygodniu przed przystąpieniem do programu oraz w tygodniu po jego zakończeniu. Chód został oceniony za pomocą systemu Vicon 250.

Wyniki

Zaobserwowano istotne statystycznie zmiany w większości parametrów czasowo-przestrzennych chodu w grupie NW: zwiększyła się szybkość chodu, długość kroku i długość cyklu. Zaobserwowano także znamienne zmiany w niektórych parametrach kinematycznych w obu grupach.

Wnioski

Badania wykazały, że udział w regularnym treningu Nordic Walking i programie rehabilitacji ruchowej wpływa pozytywnie na parametry chodu u osób z zespołem Downa. Zmiany były większe u osób, które brały udział w treningu Nordic Walking, ale obie grupy eksperymentalne prezentowały poprawę w porównaniu do grupy kontrolnej.

Słowa kluczowe: zespół Downa, trening chodu, Nordic Walking, niepełnosprawność, rehabilitacja

Introduction

Down syndrome (DS) is caused by the abnormal presence of an extra 21st chromosome. It has been proven that hypotonia, which is the most common form of neuromuscular pathology in persons with Down syndrome, is a major cause of impaired postural control and gait instability. Individuals with DS show a dysfunction of gait expressed by different values of the spatiotemporal parameters compared to the physiological norm, include a decreased step length, increased step width, longer double support phase, and decreased gait speed (Smith *et al.*, 2010, Basil *et al.*, 2016). The ability to control the gait seems to be the effect of previously acquired motor experiences. Therefore, gait-oriented training should help to modify the motor responses and improve the walk of persons with DS (Horvat *et al.*, 2012, Navas Vinagre *et al.*, 2015).

Regular physical activity performed by persons with DS may affect life expectancy and physical, mental and emotional health.

The available studies show the positive effect of rehabilitation following combined aerobic and resistance training in adult persons with DS and in healthy adults, which led to improved gait economy and exercise capacity (Mendonca *et al.*, 2015). A higher level of physical activity in participants with DS significantly reduces the incidence of cardiovascular diseases and can greatly support the assessment of the patient's functional limitations (Millar *et al.*, 1993, Rimmer *et al.*, 2004). Nordic Walking (NW) training is an effective method of increasing the mobility of joints, improving physical fitness, gait, balance and exercise tolerance, has a positive effect on the quality of life and decreases the risk of falls among elderly persons (Church *et al.*, 2002, Ołdak *et al.*, 2013, Tschentscher *et al.*, 2015, Michalak *et al.*, 2015, Leszczyńska *et al.*, 2015, Gloc *et al.*, 2015). Research has confirmed the positive effect of NW training on the health of patients without an intellectual disability, such as improving gait speed in patients with Parkinson's Disease (Reuter *et al.*, 2011). This type of training activates the muscles of the upper and lower body at the same time. Increasing the quadrangle of the base of support with poles improves stability and balance. Therefore, NW seems to be an attractive and safe form of physical activity for persons with DS. However, the available literature lacks reports on the effect of NW training on the gait of persons with DS.

We hypothesised that both kind of therapies: Nordic Walking training and rehabilitation programme (RP) would improve gait functions compared to a group that did not undergo training. The purpose of this study was to asses and compare the spatiotemporal parameters of adult persons with DS following regular Nordic Walking training and rehabilitation programme and in a group that did not undergo training during the intervention period (Control, C).

Materials and methods

The approval of the Ethical Committee of Regional Medical Chamber in Cracow had been obtained before the study.

Materials

The study involved 32 adults (16 women and 16 men) with DS and a moderate intellectual disability (IQ 36–51), aged between 25 and 40 years, attending different occupational therapy workshops in Cracow. The study participants were randomly divided into three groups: the NW Group (n = > 11 persons), which underwent a 10-week Nordic Walking training programme; the group, which attended rehabilitation programme over 10 weeks (n = > 10) or the C Group (n = > 11 persons), the control group, which did not undergo any training during the 10-week period. There were no significant differences observed in age, body mass, body height or spatiotemporal parameters between the experimental groups and the control group.

Methods

In order to evaluate gait, we used the Vicon 250 Optoelectronic System for Three-dimensional Motion Analysis, which can register the movements of the studied person, and comprises five cameras that receive infrared signals and a workstation connected to a computer, which collects and analyses the data. Two assessments were performed: in the week preceding the start of the programme (Before); and in the week after the end of the programme (After). Both assessments took place at the Biokinematics Laboratory of the Department of Biomechanics of the University of Physical Education in Cracow. Gait was evaluated based on the analysis of changes in the spatiotemporal parameters, including gait velocity, cadence, step length, stride length and step width. Finally, the gait index (walk ratio), was calculated. The walk ratio is a simple index that describes spatiotemporal parameters and represents the relationship between the amplitude and frequency of rhythmic leg movement during walking, with the walk ratio being maintained independently of speed (Sekiya *et al.*, 1996, Sekiya *et al.*, 1998).

Therapeutic procedures

The NW training and rehabilitation programme lasted 10 weeks, with three workouts a week. Each session of NW training consisted of a warm-up (10 min), the main part (45 min), and a cool-down phase (5 min). The warm-up constituted the introductory part of the training session: it was performed in a standing position, and its aim was to prepare the body for increased effort. The protocol also involved exercises requiring alternate work with the upper and the lower limbs, such as alternately raising the lower limbs to touch the opposite pole. The main part involved brisk NW. The cool-down comprised breathing and stretching exercises. The intensity progressed over the course of the training sessions. The exercises were conducted by a physical therapist, who was a qualified Nordic Walking instructor.

The original rehabilitation programme has been carried out over 30 therapeutic sessions, each lasting 60 minutes. Each session consisted of a warm-up (10 min), the main part (45 min) and final exercises (about 5 min). The programme was created based on current scientific reports, and the exercises included in it were selected specifically for the purposes of gait re-education and balance training. Rehabilitation programme consisted of coordination and stability exercises, movement range and correct posture exercises, as well as exercises in pairs and relaxing and breathing exercises. Fit balls were used for rehabilitation and the programme was conducted with progression.

Statistical analysis

Statistical analyses were performed using the StatSoft® 12.5 package (USA). ANOVA was used to compare differences between the experimental and control groups; and if its criteria were not met, the Kruskall Wallis test was used. Dependent variables were compared using the Student's *t*-test for paired variables; and if its criteria were not fulfilled, the Wilcoxon test was used. Significance was assumed at $\alpha < 0.05$ for these analyses.

Results

Comparison of spatio-temporal parameters before and after Nordic Walking training, rehabilitation programme and in the control group

The effect of the interventions on spatiotemporal parameters was analysed in the NW group, the RP group and the C group. There were no statistically significant changes in spatiotemporal parameters between the groups NW, RP and C before the intervention (Table 1, Table 2, Table 3). After the training, statistically significant changes were observed in many of the spatio parameters in the NW group, i.e. step length and cycle length increased (Table 2) Significant changes were observed in some kinematic parameters in both of the experimental groups. In the C group, no statistically significant changes were observed during gait evaluation (Table 1, Table 2, Table 3). Following NW training, a statistically significant increase in speed (Table 3), increase in cycle length for the right and left lower limb and a lengthening of step for the right and left lower limb occurred (Table 2). Statistically significant differences were found after the intervention between the groups NW and RP in cadence (Table 3) and double support values (Table 1). Both values for the RP group were closer to norm. In the RP group, only the step length for the right limb was statistically higher after the intervention (Table 2). There was a positive tendency for double support for the right and left limb after the intervention in the RP group (*p*-value 0.115 and 0.088, respectively) (Table 1).

Comparison of walk ratio in persons with Down syndrome before and after Nordic Walking training, rehabilitation programme and in the control group

There were no statistically significant changes in walk ratio between the groups NW, RP and C before the intervention. The walk ratio was statistically different between NW and RP and also between NW and C after the 10-week programme. The best value of walk ratio was found in the NW group (Table 4).

Discussion

This is the first study to compare the effects

Table 1. Temporal parameters in persons with Down syndrome before and after treatments.

Parameter		Group NW $\bar{x} \pm SD$	p*	Group RP $\bar{x} \pm SD$	p*	Group C $\bar{x} \pm SD$	p*	p** NW/RP	p** NW/C	p** RP/C
Double support R [s]	Before	0.31 ± 0.10		0.27 ± 0.06		0.22 ± 0.11		ns	ns	ns
	After	0.29 ± 0.05	0.554	0.21 ± 0.02	0.115	0.22 ± 0.07	0.981	**0.039**	0.125	0.126
Double support L [s]	Before	0.31 ± 0.09		0.26 ± 0.06		0.21 ± 0.11		ns	ns	ns
	After	0.29 ± 0.04	0.384	0.21 ± 0.02	0.088	0.20 ± 0.05	0.846	**0.044**	**0.048**	0.999
Single support R [s]	Before	0.45 ± 0.07		0.46 ± 0.04		0.46 ± 0.04		ns	ns	ns
	After	0.47 ± 0.05	0.377	0.42 ± 0.04	0.112	0.45 ± 0.05	0.956	ns	ns	ns
Single support L [s]	Before	0.46 ± 0.07		0.42 ± 0.04		0.44 ± 0.04		ns	ns	ns
	After	0.47 ± 0.06	0.687	0.42 ± 0.06	0.896	0.43 ± 0.02	0.81	ns	ns	ns
Step duration R [s]	Before	0.61 ± 0.10		0.55 ± 0.06		0.55 ± 0.06		ns	ns	ns
	After	0.60 ± 0.06	0.840	0.51 ± 0.04	0.259	0.57 ± 0.02	0.733	**0.02**	0.135	0.533
Step duration L [s]	Before	0.64 ± 0.11		0.58 ± 0.05		0.56 ± 0.08		ns	ns	ns
	After	0.61 ± 0.08	0.555	0.53 ± 0.03	0.152	0.56 ± 0.11	0.851	ns	ns	ns
Cycle duration R [s]	Before	1.23 ± 0.21		1.15 ± 0.09		1.11 ± 0.13		ns	ns	ns
	After	1.22 ± 0.13	0.986	1.03 ± 0.09	0.083	1.10 ± 0.16	0.922	**0.018**	0.173	0.439
Cycle duration L [s]	Before	1.24 ± 0.20		1.12 ± 0.11		1.09 ± 0.13		ns	ns	ns
	After	1.22 ± 0.14	0.742	1.05 ± 0.08	0.276	1.09 ± 0.15	0.875	0.051	0.11	0.848

L – left limb, R – right limb, SD – standard deviation, NW – Nordic Walking group, RP – group attending rehabilitation programme, C – control group, p – p-value, * between before and after, ** between study groups, ns – not statistically significant

of Nordic Walking training and rehabilitation programme on spatiotemporal parameters and walk ratio in persons with Down syndrome. Other studies available in the subject literature have focused on the effects of various other forms of physical activity on the balance and gait, without comparing efficiency of different kinds of treatments. The aim of this study was to evaluate the effects of 10-week Nordic Walking training and 10-week rehabilitation programme on the gait in adult people with DS, and to compare the results with a group of persons that did not undergo the therapy.

Compared to typically developing young adults, persons with DS have shown significant differences in physiological gait. Evaluations of the spatiotemporal parameters revealed a decrease in gait speed and the related parameters, such as the cadence and the length of the step and gait cycle when compared to the model of physiological gait (Horvat *et al.*, 2012, Jung *et al.*, 2017). Research has shown that people with DS are less stable during gait, which causes them to take smaller steps while walking in addition to walking slower. As reported by other authors, the abnormal gait with decreased stride width and a wide stride interval resulted from instability due to weaker lower extremity strength and a lower balance function. Considering this, increased step length and gait speed are beneficial effects in improving gait (Kubo *et al.*, 2006, Smith *et al.*, 2008).

We hypothesised that both forms of training improved gait parameters in comparison to the control group. Vicon 250 was used to evaluate gait, and the spatiotemporal parameters of gait allowed for a detailed

Table 2. Spatiotemporal parameters in persons with Down syndrome before and after treatments.

Parameter		Group NW $\bar{x} \pm SD$	p*	Group RP $\bar{x} \pm SD$	p*	Group C $\bar{x} \pm SD$	p*	p** NW/RP	p** NW/C	p** RP/C
Step length R [m]	Before	0.46 ± 0.05		0.47 ± 0.05		0.49 ± 0.10		ns	ns	ns
	After	0.52 ± 0.05	**0.009**	0.51 ± 0.04	**0.013**	0.48 ± 0.08	0.747	ns	ns	ns
Step length L [m]	Before	0.48 ± 0.07		0.47 ± 0.09		0.47 ± 0.10		ns	ns	ns
	After	0.53 ± 0.04	**0.042**	0.48 ± 0.05	0.801	0.47 ± 0.03	0.898	ns	ns	ns
Step width R [m]	Before	0.21 ± 0.05		0.19 ± 0.02		0.19 ± 0.05		ns	ns	ns
	After	0.21 ± 0.05	0.866	0.19 ± 0.03	0.901	0.19 ± 0.02	0.961	ns	ns	ns
Step width L [m]	Before	0.20 ± 0.05		0.19 ± 0.02		0.19 ± 0.05		ns	ns	ns
	After	0.20 ± 0.06	0.617	0.18 ± 0.04	0.403	0.19 ± 0.02	0.964	ns	ns	ns
Cycle length R [m]	Before	0.91 ± 0.11		0.95 ± 0.11		0.98 ± 0.19		ns	ns	ns
	After	1.05 ± 0.09	**0.004**	0.97 ± 0.08	0.577	0.97 ± 0.22	0.809	ns	ns	ns
Cycle length L [m]	Before	0.93 ± 0.12		0.94 ± 0.13		0.96 ± 0.21		ns	ns	ns
	After	1.05 ± 0.06	**0.008**	0.99 ± 0.10	0.252	0.95 ± 0.18	0.791	ns	ns	ns

L – left limb, R – right limb, SD – standard deviation, NW – Nordic Walking group, RP – group attending rehabilitation programme, C – control group, p – p-value, * between before and after, ** between study groups, ns – not statistically significant

Table 3. Spatiotemporal parameters in persons with Down syndrome before and after treatments.

Parameter		Group NW $\bar{x} \pm SD$	p*	Group RP $\bar{x} \pm SD$	p*	Group C $\bar{x} \pm SD$	p*	p** NW/RP	p** NW/C	p** RP/C
Cadence $\bar{x}$LR [number of steps/min]	Before	99.86 ± 16.31		106.38 ± 8.47		110.54 ± 12.66		ns	ns	ns
	After	99.47 ± 10.97	0.575	115.67± 8.89	0.147	109.87 ± 12.45	0.872	**0.031**	0.127	0.675
Cadence R [number of steps/min]	Before	100.50 ± 16.48		104.73 ± 7.30		109.54 ± 12.23		ns	ns	ns
	After	99.16 ± 10.76	0.678	117.33 ± 9.63	0.061	108.84 ± 7.58	0.719	**0.014**	0.155	0.407
Cadence L [number of steps/min]	Before	99.39 ± 16.55		107.87 ± 10.21		111.79 ± 13.24		ns	ns	ns
	After	99.87 ± 11.29	0.484	114.50 ± 8.24	0.299	110.89 ± 10.22	0.842	**0.047**	0.104	0.898
Speed R [m/s]	Before	0.76 ± 0.12		0.83 ± 0.13		0.91 ± 0.27		ns	ns	ns
	After	0.87 ± 0.15	**0.015**	0.95 ± 0.11	0.111	0.90 ± 0.53	0.709	ns	ns	ns
Speed L [m/s]	Before	0.76 ± 0.13		0.85 ± 0.18		0.90 ± 0.28		ns	ns	ns
	After	0.87 ± 0.14	**0.007**	0.95 ± 0.13	0.249	0.90 ± 0.78	0.72	ns	ns	ns

L – left limb, R – right limb, $\bar{x}$RL– mean for the right and the left limb, SD – standard deviation, NW – Nordic Walking group, RP – group attending rehabilitation programme, C – control group, p – p-value, * between before and after, ** between study groups, ns – not statistically significant

Table 4. Walk ratio in persons with Down syndrome before and after treatments.

Parameter		Group NW $\bar{x} \pm SD$	p*	Group RP $\bar{x} \pm SD$	p*	Group C $\bar{x} \pm SD$	p*	p** NW/RP	p** NW/C	p** RP/C
Walk ratio R [mm/(step/min)]	Before	4.73 ± 0.88		4.47 ± 0.59		4.49 ± 0.66		ns	ns	ns
	After	5.30 ± 0.50	0.139	4.40 ± 4.40	0.745	4.46 ± 0.66	ns	**0.015**	**0.013**	0.981
Walk ratio L [mm/(step/min)]	Before	5.00 ± 1.21		4.33 ± 0.73		4.21 ± 0.70		ns	ns	ns
	After	5.37 ± 0.60	0.311	4.07 ± 4.07	0.429	4.29 ± 0.66	ns	**0.001**	**0.003**	0.768

L – left limb, R – right limb, SD – standard deviation, NW – Nordic Walking group, RP – group attending rehabilitation programme, C – control group, p – p-value, * between before and after, ** between study groups, ns – not statistically significant

assessment before and after the interventions. The comparison of the results between both experimental groups (NW and RP) and the control group (C) revealed statistically significant changes ($p < 0.05$) in a considerable number of parameters in the NW group. After the 10-week training programme, the length of the step increased in both lower limbs, as did the length of the gait cycle. Nordic Walking training also significantly increased the gait speed of persons with Down syndrome. These changes were not observed in the RP group. According to Rodenbusch (2013), participants with DS who trained on a treadmill seemed to develop adaptations in cadence similar to typical children. It is believed that increased length of the gait cycle and speed results from biomechanical adaptation during treadmill training and NW training (Gouelle *et al.,* 2016). Additionally, to compare the impact of the interventions on spatiotemporal parameters, the gait index was calculated for all groups, and its changes between the groups were compared. Walk ratio is considered to be an effective tool for summarising spatiotemporal parameters (Sekiya *et al.,* 1998, Gouelle *et al.,* 2016). The walk ratio enables the assessment of deviation from normal walking patterns. Walk ratio decreases consistently with age: 6.4 for young persons and from 5.5 to 4.4 for older persons; older adults tend to walk with shorter steps (Sekiya *et al.,* 1996, Nagasaki *et al.,* 1996, Sekiya *et al.,* 1998). After the 10-week training programme, the walk ratio was closer to the norm in the NW group and was statistically different between the Nordic Walking and Controls and also between the Nordic Walking and persons attending rehabilitation programme. Verifying research results concerning the effectiveness of NW training for gait re-education in persons with DS is difficult due to limited literature on the subject. There are studies that have been conducted in other groups, which indicate the effectiveness of NW training in improving the gait. It was proven that an 8-week NW training in a group of healthy postmenopausal women improved their biomechanical parameters of gait. Similarly, as with the present research, a significant increase in gait speed and step length occurred (Hagner-Derengowska *et al.,* 2015). The obtained results showed that a 10-week period of RP provided few statistically changes in spatiotemporal parameters. Nonetheless, the gait did not change for the worse. Different studies show that adults with DS significantly improved gait parameters after a period of rehabilitation. The participants have been taking part in special rehabilitation exercises for 10 months (Marchewka and Chwała, 2008). According to results, a longer period of time or an intensive, focused therapy is necessary. The results indicate that the 10-week NW training programme induced changes in the spatiotemporal parameters and improved the quality of walking compared to rehabilitation programme and the C group. This indicates the possible benefits of NW training for gait rehabilitation in persons with DS.

There are some limitations of this study that should be addressed. The participants of our study took part in 10-week training, which may be too short to achieve an optimal effect of this type of therapy in adults with

DS. Moreover, we did not analyse behavioural factors or cognitive dysfunction, which may be confounding factors in the assessment of the applied therapy.

Conclusions

1. Nordic Walking training is better method of improving spatiotemporal parameters in persons with Down syndrome than rehabilitation programme, causing an increase in gait speed and steps length.
2. Walk ratio was statistically different between Nordic Walking training group and group attending in rehabilitation programme and also between Nordic Walking training group and control group after a 10-week programme. The best value of walk ratio occurred in Nordic Walking training group.
3. Based on our results, we can suggest that the applied Nordic Walking training programme is effective and should be included as a part of daily training programme of persons with Down syndrome.
4. Practical implication is an optimum Nordic Walking training in persons with Down syndrome should be incorporated in daily, obligatory activity.

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Data Availability

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

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