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ORIGINAL

Effects of a circuit training including plyometric jumps on cardiorespiratory fitness of children and adolescents with Down syndrome

A. González-Agüero[a,b], A. Gómez-Cabello[a,c], A. Matute-Llorente[a,d], A. Gómez-Bruton[a,d], G. Vicente-Rodríguez[a,d] and J.A. Casajús[a,d,*]

[a]*Grupo de investigación GENUD (Growth, Exercise, Nutrition and Development), Universidad de Zaragoza, Zaragoza, Spain*
[b]*Department of Sport and Exercise Science, Aberystwyth University, Ceredigion, United Kingdom*
[c]*Centro Universitario de la Defensa, Zaragoza, Spain*
[d]*Departamento de Fisiatría y Enfermería, Facultad de Ciencias de la Salud y del Deporte, Universidad de Zaragoza, Huesca, Spain*

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Exercise;
Functional residual capacity;
Down syndrome;
Treadmill test;
Health

Abstract
Aim: To ascertain the effects of 21 weeks of circuit training, including plyometric jumps, on cardiorespiratory fitness of youths with Down's syndrome (DS).
Methods: Twenty-seven children and adolescent aged 10 to 19 years with DS participated in this study and were divided in two groups: exercise (EXE, n=14) and control (CON, n=13). Work time, peak values of oxygen consumption, respiratory exchange ratio, heart rate and minute ventilation of the participants were measured pre- and post-training with a graded exercise treadmill test.
Results: EXE group increased all their cardiorespiratory parameters compared to baseline after 21 weeks of training (all $P<.05$). Additionally, and despite having similar pre-training values, the EXE group showed higher values than the CON group in all cardiorespiratory parameters after training (all $P<.05$).
Conclusion: It may be concluded that youths with Down syndrome can achieve improvements in several cardiorespiratory parameters when performing 21 weeks of training including plyometric exercises.

*Author for correspondence.
E-mail: joseant@unizar.es (J.A. Casajús).

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PALABRAS CLAVE:
Ejercicio;
Capacidad funcional;
Trisomía 21;
Tapiz rodante;
Salud

Efectos del entrenamiento pliométrico sobre la resistencia cardiorrespiratoria de niños y adolescentes con síndrome de Down

Resumen

Objetivo: Determinar los efectos de 21 semanas de entrenamiento en circuito, incluyendo saltos pliométricos sobre la resistencia cardiorrespiratoria de jóvenes con síndrome de Down (SD).

Método: Veintisiete jóvenes con SD de entre 10 y 19 años participaron en este estudio. Los participantes se dividieron en dos grupos: ejercicio (EJE; n = 14) y control (CON; n = 13). Antes y después de la realización del programa de entrenamiento se midieron los siguientes parámetros: tiempo de trabajo, valores máximos de consumo de oxígeno, cociente respiratorio, frecuencia cardíaca y ventilación minuto de los participantes mediante una prueba de esfuerzo progresiva en tapiz rodante.

Resultados: Los participantes del grupo EJE aumentaron todos los parámetros cardiovasculares en comparación con su valor basal, después del entrenamiento (todos $p < 0{,}05$). Además, a pesar de tener unos valores similares antes del entrenamiento, el grupo EJE mostró valores más elevados que el grupo CON después del entrenamiento (todos $p < 0{,}05$).

Conclusión: Se puede concluir que los jóvenes con síndrome de Down pueden conseguir mejoras en diversos parámetros cardiorrespiratorios tras la ejecución de 21 semanas de entrenamiento con ejercicios pliométricos.

Introduction

Down syndrome (DS) is a genetic condition characterised by the presence of intellectual impairment and more than 80 clinical characteristics[1], some of which are associated with exercise[2]. It has been reported that cardiorespiratory fitness (CF) is lower in individuals with DS compared with others without DS, with or without intellectual impairment[3,4]. This is important, since CF is an important heath indicator during childhood and adolescence, mainly due to its inverse relationship with abdominal and total adiposity, and its direct relationship with the reduction in cardiovascular risk factors, as well as with bone health[5]. Furthermore, it is also known that CF positively contributes to the freedom of the individual with special needs (such as those with DS) in their adult life[6], and favours the ability to carry out activities of daily living due to its close relationship with functional capacity[7].

Therefore, partly due to the increase in life expectancy of individuals with DS[8], and with the aim of increasing their independence and quality of life, CF could be a key factor to be investigated from childhood to adolescence in a population with DS.

It is well known that training programmes improve CF in children and adolescents, with or without special needs (such as type I diabetes, intellectual impairment or cerebral palsy[9-11]); however, it has not been investigated in detail whether these results can also be observed in children and adolescents with DS[4]. As has been reported in the scientific literature, using a systematic review, aerobic training is an effective strategy to improve CF in adults with DS[12]. Unfortunately, there are very few studies conducted exclusively on children and adolescents with DS[13-15], and the information that they provide is not conclusive as regards improvements in CF. Due to its intrinsically cyclic and rhythmic nature, aerobic training could not be particularly attractive for children with DS. Alternatively, circuit training is associated with play activities characterised by different exercises. Using low intensities and a high number of repetitions, it effectively combines the benefits of muscle strength training with the cardiovascular benefits of dynamic exercise. This type of training produces around 50% of the improvement in CF compared with cycling or continuous running in individuals with a disability[16], and it has been demonstrated that it improves body composition in adolescents with DS[17,18]. Significantly, plyometric training has also shown to produce increases in strength and power in the lower limbs, as well as improvements in the efficiency of the run and jump[19]. It has also been demonstrated that plyometric training is effective for increasing the maximal oxygen consumption (VO_{2max})[20].

Therefore, the aim of this study was to determine the effects of 21 weeks in a circuit training programme, including plyometrics (2 days a week, 25 minutes) on the CF of children and adolescents with DS.

Material and methods

Participants

A total of 27 children and adolescents with DS (12 girls and 15 boys), from 10 to 19 years when starting the study, took part. Fourteen of them (8 girls and 6 boys) were randomly assigned to the exercise group (EXE) and carried out the training programme, while the remaining 13 participants (CON group) did not increase their daily activities. A clinical record was completed, including the disease history and surgical interventions of each participant. The participants and their parents were informed of the aims of the study, possible risks and benefits. The study was conducted in accordance with the Helsinki Declaration of 1961(revised in

Edinburgh, 2000) and was approved by the Government of Aragon Clinical Research Ethics Committee (CEICA, Spain).

Evaluation and measurements

Anthropometry

A record was made of the height of all the participants, without shoes and the minimum of clothes, with a precision of 0.1 cm (SECA 225, SECA, Hamburg, Germany), and weighed with a precision of 0.1 kg (SECA 861, SECA, Hamburg, Germany). The body mass index (BMI) was calculated as the weight (kg) divided by the height squared (m^2).

Evaluation of puberty status

The sexual maturity status was determined by observation by a doctor using the 5 states proposed by Tanner and Whitehouse[21].

Strength test

Before the maximum strength test, a cardiologist examined each participant and giving them permission to take part in the study. The participants were familiarised with the laboratory and test protocols before collecting the data. The recording of data started when the participants were able to walk on the treadmill (Quasar Med 4.0, h/p/cosmos, Nussdorf-Traunstein, Germany) with the gas mask already in place. A progressive protocol was used to evaluate CF (table 1). Each participant was started with a comfortable rhythm (2.4 or 3.2 km·h^{-1}), then the speed was increased by 0.8 km·h^{-1} every 2 minutes (min) until the participants were unable to walk without running (4.8 or 5.6 km·h^{-1}). From that time, the incline of the treadmill was increased by 4% every minute until exhaustion (up to a maximum of 24%). A doctor specialised in sports medicine supervised the whole test and examined the participants before and after the test.

Table 1 Stress test protocol

Speed (km/h)	Incline	Time (min)
0.0	0°	3
2.4	0°	2
3.2	0°	2
4.0	0°	2
4.8	0°	2
5.6	0°	2
5.6	4°	1
5.6	8°	1
5.6	12°	1
5.6	16°	1
5.6	20°	1
5.6	24°	1
0.0	0°	3

The respiratory gases exchange was measured "breath by breath" using an open-circuit ergospirometer (Oxycon Pro, Jaeger/Viasys Healthcare, Hoechberg, Germany). The peak oxygen uptake values (VO_{2max}), respiratory quotient (RER_{max}), and peak minute ventilation (VE_{max}) were recorded as the highest mean values obtained for any continuous 30 second period. The gas analyser was calibrated with a gas mixture of known volumes before the first test each day, as recommended by the manufacturer. A 12-lead electrocardiogram (ECG) was used to record the heart rate before and during the whole test. The maximal heart rate value (HR_{max}) was considered as the highest HR value recorded during the last stage of the exercise. The blood pressure was also measured, for safety reasons, before the test and in the recovery period (M3, HEM-7200-E, Omron Healthcare Europe, Hoofddorp, Netherlands). These test were performed pre- and post-training, and the increases in the VO_{2max}, RER_{max}, HR_{max}, VE_{max}, and the work time was calculated individually for each participant using the formula [(post-pre)/pre] × 100.

Intervention programme

The participants assigned to the EXE group exercised 2 days a week, and each session was performed with a maximum of 10 participants. There was a 48 hour rest period between the 2 sessions during the whole training programme. Each training session was supervised by a graduate in Physical Activity and Sport Sciences and one of three helpers. The sessions were carried out in three different locations: two exercise rooms in different gymnasiums in the city, and one room adapted by the Fundación Down Zaragoza. The same material was used in all the sessions. The first week (2 sessions) were used for familiarisation with the use of the material/equipment, and how to perform the exercises. Each session consisted of 5 min of warm-up activities, 10 to 15 min physical exercise, and 5 min to calm down again. The circuit consisted of 4 main components in accordance with the training plan (fig. 1).

The exercises performed at each station were:

1. **Jumps:** standing vertical jump, run and jump, drop jump (jump height between 40 and 50 cm), drop jump + horizontal jump (jump height between 40 and 50 cm). From the third week, the participants performed the exercises carrying medicine balls.
2. **Wall push-ups:** The participants placed their hands on the wall and performed foot stretches with the feet apart, 30 to 50 cm from the wall.
3. **Fitness elastic bands:** side row, biceps stretch and frontal row.
4. **Adapted medicine balls:** throwing and receiving, with a distance between participants of 3 to 4 m.

The 13 participants were divided into four intensity groups (quartiles) depending on their body weight, and worked individually. The participants were transferred to the next intensity group each time they were able to perform the prescribed exercise easily and with a suitable

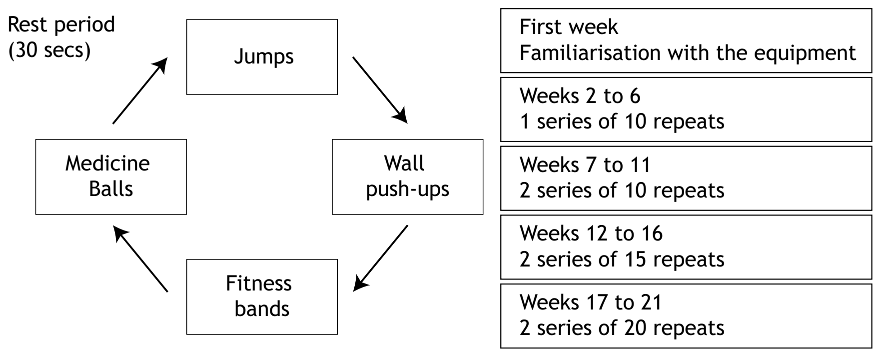

Figure 1 Training plan for the 21 weeks.

biomechanical movement. There were four different colours, according to intensities for the fitness bands (yellow, green, blue and violet), and the four medicine balls (1, 2, 3 and 4 kg), each one being assigned to a group. The participants were encouraged to use positive verbal reinforcement during the whole training period, focusing on the correct execution of the exercises and the number of repetitions. Each group followed the same exercise programme with a fitness band and a medicine ball of a different colour (fig. 1). A minimum attendance of 70% was the cut-off point to include the data in the subsequent statistical analysis.

Statistical analysis

The mean and standard deviation are shown as descriptive statistics, on not being the case, they are explained below. ANOVA tests were performed to evaluate any gender differences by training group. The χ^2 test was used to evaluate the differences in the Tanner maturity state. Non-parametric tests were used due to the sample size (less than 30 participants). To evaluate the differences between the EXE and CON groups (between variables and between percentage changes), the Mann-Whitney U test was used, with the Wilcoxon-Cox test being used to evaluate the differences between before and after the training and within each group for all the variables studied. As the HR_{max} increased pre- to post-training, an ANOVA was calculated for the VO_{2max}, being controlled by HR_{max} (ANCOVA). The size effect of the sample was established using the Cohen *d* test for all the comparisons[22]. Using the cut-off points established by Cohen, the size effect may be small (from 0.2 to 0.5), medium (from 0.5 to 0.8), or large (greater than 0.8). Statistical significance was established at $P<.05$. All the statistical analyses were carried out using the SPSS program, version 15.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Adherence to the training

The adherence to treatment had a mean of 81.8 ± 9.2%. Only one of the participants (female) did not reach the 70% minimum attendance for training (45%), and her data were excluded from the statistical analysis. There were no drop-outs in any group, and there no significant adverse effects or health problems in the participants of either group during the training period.

Physical characteristics

The age and physical characteristics of the participants are summarised in table 2. The EXE and CON groups show similar values for height, weight, Tanner state, and BMI, before and after the intervention.

Cardiorespiratory values

No group differences were found due to training for any CF parameter (data not shown). There were also no differences by sex, thus the groups were studied together (with no gender divide). Table 3 shows the mean and standard deviation of the peak values of the CF data for the EXE and CON groups, at pre- and post-training times. There were no differences between groups before training for any of the variables studied. Subsequently, the EXE group showed higher values of VO_{2max}, HR_{max} and RER_{max} compared with the CON group (all $P<.05$, Cohen *d* varied between 0.6 and 0.9; table 3). The subsequent adjustment controlling for the percentage change in HR_{max} (pre and post-training) did not significantly change the results for the VO_{2max} (data not presented). The EXE group also increased its work time, VO_{2max}, HR_{max}, VE_{max} and RER_{max} at pre- to post-training times, whilst the CON group only improved the VE_{max} (all $P<.05$, table 3). The mean percentage change values, calculated individually at pre- and post-training times are shown as a graph in figure 2. In general, the EXE group showed a greater tendency to improvement in all the CF measurements compared with the CON group (with no significant differences).

Discussion

In general, the results of the study show that children and adolescents with DS increased some parameters of their CF after performing circuit training for 21 weeks. As far as we know, this is the first study that has obtained significant improvements in the CF of children and adolescents with DS as a result of a training programme. As there were no drop-outs, it could be said that the programme is attractive and of easy adherence for this population and their families.

Given that individuals with DS have a high oxygen consumption on walking[23], and that CF is a good predictor of the capacity of adults with DS to perform functional tasks of daily living[24], we are talking about very important conclusions, that could improve the performing of daily activities and their independence, now and in subsequent years. Taking into account that CF is strongly associated with present and future cardiovascular health of young

Table 2 Descriptive characteristics of the participants

	Pre-training						Post-training					
	Exercise n = 13			Control n = 13			Exercise n = 13			Control n = 13		
	Mean	±	*SD*	*Mean*	±	*SD*	*Mean*	±	*SD*	*Mean*	±	*SD*
Age (years)	13.7	±	2.6	15.6	±	2.5	14.3	±	2.6	16.2	±	2.5
Weight (kg)	40.1	±	9.6	47.9	±	10.7	41.8	±	9.8	48.6	±	10.4
Height (cm)	141.9	±	12.5	146.7	±	11.1	142.8	±	12.4	148.1	±	10.6
Tanner (I/II/III/IV/V)	3/0/3/2/5			1/2/1/4/5			2/1/2/2/6			0/3/1/3/6		
BMI	19.3	±	2.5	22.1	±	3.3	20.2	±	2.6	21.39	±	3.0

BMI: Body mass index.

people[5], it is an important factor to decrease the higher risk of cardiovascular diseases and diseases associated with bone health in this specific population[4,25-27]. Although individuals with DS may have less atherosclerosis risk factors[28], the continual increase in life expectancy in the DS population[29], together with high levels of adipose tissue found in this population (particularly in the trunk)[25] means that the increases in CF may be an important topic to be taken very much into account.

Previous studies in adolescents and young people with DS showed improvements in work capacity after training[13,30], but without achieving increases in CF parameters. Millar et al.[30], after a 10-week aerobic training programme with adolescents with DS, found an improvement in walking capacity. On the other hand, studies conducted on adults with DS showed consistent results in improvements in the VO_{2max}[23,31,32], among other cardiovascular parameters. The fact that only individuals without congenital heart diseases were included in previous studies complicates the comparison with our results. Given that approximately 40% of individuals with DS have congenital heart diseases[1], it was decided to include them, with the aim of being able to generalise the results to the population of adolescents with DS. Despite the fact that we did not find any group differences due to training, increases were found in pre- and post-training VO_{2max}, among other cardiovascular

Table 3 Pre- and post-exercise cardiorespiratory fitness values

	Pre-exercise						Post-exercise					
	Exercise			Control			Exercise			Control		
	Mean	±	*SD*	*Mean*	±	*SD*	*Mean*	±	*SD*	*Mean*	±	*SD*
Exercise time (min)	14.4	±	1.7	14.5	±	1.7	15.5	±	1.13†	14.6	±	2.2
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	33.1	±	3.2	30.1	±	7.2	36.4	±	3.6†	33.1	±	3.3*
RER_{max} (VCO_2/VO_2)	1.02	±	0.09	1.01	±	0.09	1.10	±	0.08†	1.04	±	0.09*
VE_{max} (L/min)	42.7	±	14.8	44.6	±	11.9	52.6	±	15.1†	51.3	±	13.8†
HR_{max} (bpm)	167.4	±	10.3	165.6	±	8.9	175.5	±	10.1†	166.7	±	12.6*
VO_{2max} (controlling HR_{max})	32.8	±	5.1	31.7	±	5.1	36.2	±	3.8	33.9	±	3.8[a]

HR_{max}: maximal heart rate; RER_{max}: maximal respiratory quotient; VE_{max}: maximal ventilation; VO_{2max}: maximal oxygen consumption.
†*P*<.05 Pre-*vs*. Post-exercise.
**P*<.05 EXE *vs*. CON.
[a]*P*=.06.

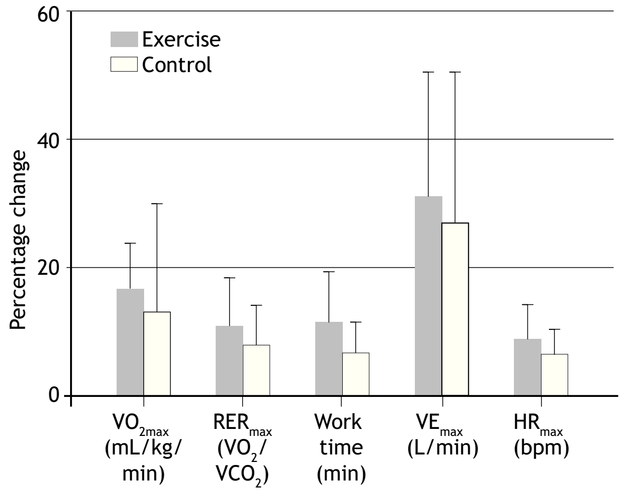

Figure 2 Mean values and standard deviation of the percentage changes in the cardiovascular variables for each group from pre- to post-training.

HR_{max}: maximal heart rate; RER_{max}: maximal respiratory quotient; VE: maximal minute ventilation; VO_{2max}: maximal oxygen consumption.

parameters in the EXE group. Although it cannot be considered that these increases were only as a result of the training programme, perhaps the development observed in the both in the EXE and CON group could favour the increase in these parameters.

The full duration of previous training programmes was from 12 weeks (3 or 4 times per week) to 28 weeks (twice per week). Our results indicate that a training programme of 21 weeks, twice a week, in young people with DS could be useful to improve some of their CF parameters. Despite the short duration of this training, this study is not against the promotion of physical activity. In fact, this type of training also improves the body composition of young people with DS[17,18], thus, whenever possible, longer and more intense training programmes could be introduced.

It is important to highlight that, even before starting the training period, the VO_{2max} values of our participants were higher than the values observed in previous studies. The mean values ($ml \cdot kg^{-1} \cdot min^{-1}$) varied from 30.1 to 36.4 in our study, compared to 31.1 to 32.1 by Varela[13], 25.5 to 26.9 in the study by Millar[30], and 29.6 to 35.7 by Tsimaras[32]. Effectively, according to the percentile curves for VO_{2max} in individuals with DS, designed by Baynard et al.[3], the participants of the present study showed levels above the 70 percentile. This fact could explain the lack of differences observed, as to achieve increases in CF is more complicated when it starts from a higher baseline.

Plyometric trained has demonstrated that it is useful to increase muscle strength (mainly in the legs) and running performance[19]. As leg strength may contribute to the VO_{2max} in individuals with intellectual impairment[33], and the type of maximum test performed in this study requires greater leg strength, the increase in the CF parameters could be partly explained by increase in leg muscle strength and an increase in resistance to peripheral fatigue due to this training. On the other hand, Rimmer[34] proposed to explore the magnitude of the change in VO_{2max} that can be achieved through a strength only programme. Cowley et al.[24] showed that the increases in leg strength, by means of progressive resistance training only, did not affect the aerobic capacity in individuals with DS. Our results in VO_{2max} were similar to those observed when aerobic and strength training are combined in adults with DS[31]. However, as a population in growth was studied, it could be said that the maturity development itself may have also contributed to these gains, and for that reason no differences were found in the CF parameters.

Limitations and strengths

This study is not exempt from limitations, which must be recognised. In the first place, the maximum strength test is dependent on effort and, as a result, the hypothesis may be put forward that the participants with DS make less effort, or that they may try harder in the post-training evaluation. However, the fact that our participants may have performed 4 or 5 maximum tests previously, leads us to believe that our data were not influenced by lack of effort in the participants. Also, the differences in VO_{2max}, even after adjusting for HR_{max}, is a good indicator of the effort made. The protocol used had not been previously validated in this population; however, it fulfilled the criteria established for a stress test: progressive increases in effort until the point that the participant simply refuses to continue exercising. Also, as regards the protocol, as mentioned before, greater strength in the lower limbs can help the participant achieve higher exercise levels in this progressive protocol. Thus, plyometric training could have increased the resistance to peripheral fatigue of the participants, this being partly the cause of the increases in CF. Secondly, the training proposed was not a normal strength training, on the basis of the work in different percentages of maximum repetition on different equipment in a gymnasium. Simple exercises, without complex material are considered better for the training of individuals with intellectual impairment. And, finally, our experimental design did not include a control group of young people without incapacity, who carried out the same training as the EXE group. Thus, the level at which these results would be produced similarly in controls without DS is still unknown. Although the inclusion of participants with congenital heart disease can make comparisons with previous studies difficult, it is important to remember that this decision is based on the fact that approximately 40% of individuals with DS have congenital heart diseases[1]. Excluding these young people would make it impossible to generalise the results of this study to all young people with DS. The strengths of this study were: the inclusion of both sexes in the design, the use of a control group of young people with DS, the use of a laboratory stress test to evaluate cardiovascular parameters, and sample size, which although not too large, is larger than any other study conducted up until now that has included training in children and adolescents with DS. Furthermore, the size effect was determined by Cohen *d* tests, demonstrating consistency of the data.

Conclusion

Our findings suggest that circuit training including plyometrics can be useful to improve CF of young people with DS. The fact that this type of training also may reduce the fat mass and increase bone mass in these same individuals gives great importance to these findings. Body composition and physical condition are closely related to health and functional capacity, thus individuals with DS can significantly benefit from these improvements. Future investigations should be conducted to explore other training methods that take up less time for the families, and that are much easier to perform by the participants, and much easier to monitor by the specialists.

Conflict of interests

The authors declare that there are no conflicts of interests that could affect the contents of this work.

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