JRSR 11 (2024) 109-116

Journal of Rehabilitation Sciences and Research

Journal Home Page: jrsr.sums.ac.ir

Original Article

Effect of Eight Weeks of Combined Turning Exercises on the Performance of Female Educable Students with Down Syndrome: A Clinical Trial

Negar Heidari[1], MSc; Gholamali Ghasemi[1*], PhD; Morteza Sadeghi[1], PhD; Negin Ghasemi Kahrizsangi[2], MD

[1]Department of Sport Injuries and Corrective Exercise, Faculty of Sport Sciences, University of Isfahan, Isfahan, Iran
[2]Isfahan University of Medical Sciences, Isfahan, Iran

ARTICLE INFO

Article History:
Received: 17/05/2023
Revised: 18/06/2023
Accepted: 29/08/2023

Keywords:
Down syndrome
Muscle strength
Student
Turning exercises

Please cite this article as: Heidari N, Ghasemi GA, Sadeghi M, Ghasemi Kahrizsangi N. Effect of Eight Weeks of Combined Turning Exercises on the Performance of Female Educable Students with Down Syndrome: A Clinical Trial. JRSR. 2024;11(2):109-116. doi: 10.30476/JRSR.2023.98915.1373.

ABSTRACT

Background: The present study focuses on elucidating the effects of an eight-week combined turning exercise program on the physical performance of female students with Down syndrome (DS), a genetic disorder characterized by intellectual disability and often associated with weaker muscle strength. Individuals with DS typically exhibit reduced muscle strength due to a lower percentage of slow-twitch muscle fibers and a diminished overall number of muscle fibers.
Methods: In this semi-experimental clinical trial, the authors used purposive sampling to enroll 26 female students diagnosed with DS. Participants were randomly divided into an experimental group (n=13; mean age: 12.15±1.62 years, mean height: 139.23±8.94 cm, mean weight: 42.62±13.44 kg, mean IQ: 63.02±5.54) and a control group (n=13; mean age: 12.23±1.53 years, mean height: 141.15±10.31 cm, mean weight: 45.46±15.94 kg, mean IQ: 63.05±5.49). The authors evaluated muscle strength using a hand-held digital dynamometer, push-up test, long jump, and sit-up before and after the eight-week training period. The experimental group underwent a combined turning training program lasting 45-60 minutes daily, thrice a week, for eight weeks. We analyzed the data using repeated measures analysis of variance (ANOVA) with a significance level set at P≤0.05.
Results: The findings revealed a significant enhancement in physical performance among participants in the experimental group compared to those in the control group (P≤0.05). Specifically, the combined turning exercise program positively influenced upper body, middle body, and lower body muscle strength in female students diagnosed with DS.
Conclusion: The results of this investigation imply that incorporating combined turning exercises could serve as an effective strategy for enhancing muscle strength among female students diagnosed with DS. Integrating these exercises into rehabilitation programs tailored for individuals with DS may improve their physical performance and enhance their overall quality of life.

Introduction

Down syndrome (DS), a prevalent genetic disorder occurring in approximately 1 in 800-1200 live births [1], affects a considerable number of individuals worldwide, with over 200,000 people living with this condition in the United States alone [2] with 5000 additional children with DS born annually. Trisomy 21, accounting for about 95% of DS cases, underlies most syndrome instances. DS presents various medical challenges, including intellectual disabilities, cardiac anomalies, and respiratory complications [3]. Individuals with DS exhibit distinct

Corresponding author:* Gholamali Ghasemi, PhD; Department of Sport Injuries and Corrective Exercise, Faculty of Sport Sciences, University of Isfahan, Isfahan, Iran. **Tel: +98 9131299817;
Email: gh.ghasemi@spr.ui.ac.ir

anatomical and physiological traits, distinguishing them from the general population [3, 4]. This paper investigates the implications of muscle weakness in DS individuals and the potential role of physical activity in enhancing muscle strength within this demographic.

Children with DS often demonstrate weaker muscle strength, slower speed, and inferior static and dynamic balance compared to typically developing children of the same age. These motor skill deficiencies are attributed to factors such as ligamentous laxity and low muscle tone, which are prevalent in individuals with DS. The weaker muscle strength observed in this population can be attributed to various factors, including a lower percentage of slow-twitch muscle fibers and a reduced number of muscle fibers. Consequently, individuals with DS are at a heightened risk of falls due to poor balance and lower limb muscle weakness. Furthermore, muscle weakness and hypotonia, particularly in the lower limbs, can impede overall physical health and the performance of daily activities. Research indicates that individuals with DS exhibit lower levels of muscle strength development compared to their healthy counterparts. However, engaging in physical activity has been shown to significantly enhance muscle strength in individuals with DS, underscoring its importance in improving physical health and overall quality of life in this population.

Children with DS often demonstrate weaker muscle strength, slower speed, inferior static and dynamic balance, lower visual control, as well as limited fine and gross motor skills compared to typically developing children of the same age [5]. These motor skill deficiencies are attributed to factors such as ligamentous laxity and low muscle tone, which are prevalent in individuals with DS [6]. The weaker muscle strength observed in this population can be attributed to various factors, including a lower percentage of slow-twitch muscle fibers and a reduced number of muscle fibers. Consequently, individuals with DS are at a heightened risk of falls due to poor balance and lower limb muscle weakness [7]. Furthermore, muscle weakness and hypotonia, particularly in the lower limbs, can impede overall physical health and the performance of daily activities [8]. Research indicates that individuals with DS exhibit lower levels of muscle strength development compared to their healthy counterparts [9]. However, engaging in physical activity has been shown to significantly enhance muscle strength in individuals with DS, compared to those with other intellectual disabilities [10], underscoring its importance in improving physical health and overall quality of life in this population.

Engaging in physical activity plays a vital role in mitigating health issues associated with sedentary behavior and physical inactivity, both of which are prevalent among individuals with DS [11]. For individuals with intellectual disabilities, maintaining an independent lifestyle is paramount, and physical activity serves as a cornerstone for achieving this goal. It offers an avenue for individuals to partake in physical training, fostering an active and self-sufficient life as they transition into adulthood. Thus, integrating physical activity into daily routines is indispensable for promoting health and well-being in this population [12]. Numerous studies have underscored the efficacy of various exercises and physical activities in enhancing physical fitness parameters among individuals with DS. Activities such as swimming [13], exercise therapy [14], trampoline exercises [15], and strength and balance training [16] have been shown to bolster aerobic capacity, muscle strength, balance, flexibility, body composition, and motor skills in this population. Additionally, research supports the benefits of a combined training regimen in improving motor performance, balance, and muscle strength among individuals with DS [17].

Turning exercises involve rotations around one or more axes, vertically or horizontally, at various joints or throughout the entire body. These exercises come in diverse forms and methods, including pivot exercises, twisting movements, swinging actions, directional changes, and multi-planar activities. They can target specific body parts such as the shoulders, hips, and core or involve the entire body. Turning exercises can be standalone or integrated with other training objectives, such as enhancing balance, strength, or core stability.

Executed across different axes, turning exercises demand coordination among various body systems and structures, leading to rapid improvements. Their multi-planar nature, involving movements in multiple directions, renders them more challenging and impactful than conventional exercises. Moreover, their resemblance to everyday movement patterns enhances their practical applicability [18].

Studies suggest that multi-plane exercises, like turning movements, offer superior benefits in neuromuscular integration, stability, and functional transfer compared to linear or single-plane exercises [19]. Furthermore, the complexity of turning exercises stimulates brain activation, enhances muscle coordination, and promotes cortical reorganization, ultimately improving overall performance [20].

The primary objective of this study was to assess the impact of an eight-week regimen of combined turning exercises on the physical performance of educable students diagnosed with DS. Given the adaptable nature of turning exercises, they present a promising avenue for the rehabilitation and physical conditioning of individuals with DS. Despite the potential benefits, there is a notable gap in the existing literature regarding the effects of combined turning exercises specifically tailored for individuals with DS.

Methods

This study employed a controlled clinical trial with a two-group design, comprising an experimental group subjected to turning training and a control group without such intervention. The research followed a pre-test and post-test assessment protocol. Ethical approval for the study was obtained from the Isfahan University ethics committee under the code of ethics IR.UI.REC.1401.043. The target population encompassed all female students aged 9 to 14 diagnosed with DS in Isfahan. Utilizing G-Power software, a sample size of 26 participants was determined, achieving a power of 0.8. Participants were randomly paired based on IQ scores and subsequently allocated into two groups, each consisting of 13 individuals: an experimental group and a control group.

Before commencing the study, written consent was obtained from the participants' parents. Participants underwent an evaluation based on demographic characteristics and physical health status, which included age, IQ, height, weight, and cardiovascular and pulmonary health. All participants were deemed physically healthy, with IQs ranging from 50 to 70. Inclusion criteria for the study encompassed individuals identified as educable mentally disabled individuals with DS, as diagnosed by a physician, with an IQ falling within the range of 50 to 70. Additionally, participants were required to exhibit no signs of sexual maturity, absence of other disabilities or special diseases, and obtain consent from both parents and the participants to participate in the study. Exit criteria involved several conditions: absence from over 30% of training sessions for experimental group participants, voluntary withdrawal from the study, the occurrence of unforeseen problems hindering participation, or failure to complete research tests. Notably, all 26 participants completed the study.

Muscle strength was assessed utilizing a handheld digital dynamometer (manufactured by j-Teck, America) (Figure 1). The reliability and validity of this dynamometer have been extensively demonstrated across various studies, yielding intragroup correlation coefficients of 0.94 [21] and a range of correlation coefficients from 0.40 to 0.71 [22].

Muscle strength was assessed following the instructions provided by the device. For the limb muscle groups, muscle strength assessment was conducted using a break test at the mid-range of the muscle length (Figure 2). To evaluate the strength of the elbow flexor muscles, participants were seated comfortably with their elbows flexed at 90 degrees. The dynamometer was positioned on the end of the forearm in supination, and the strength of this muscle group was measured. Similarly, to assess the strength of the elbow extensor muscles, participants were seated with their elbows flexed at 90 degrees. The dynamometer was placed on the end of the forearm in pronation, and the strength of this muscle group was measured.

To assess the strength of the hip extensor muscles, participants were positioned on all fours, and the dynamometer was placed on the end of the femur. The strength of this muscle group was then measured.

Figure 1: Handheld digital dynamometer

Participants were placed on their side for the hip abductor muscles, and the dynamometer was positioned on the lateral condyle of the femur to measure the strength of this muscle group. Participants lay on their stomachs to evaluate the strength of the knee flexor muscles, and the dynamometer was placed on the end of the calf to measure the strength of this muscle group.

To evaluate the strength of the trunk flexor muscles, participants lay completely on their back, and the dynamometer was positioned on the chest. Participants then raised their heads and trunks to an angle of 45 degrees against resistance, and the strength of this muscle group was measured. Participants were placed on their stomachs for the trunk extensor muscles, and the lower body was secured to the bed. The dynamometer was placed between the scapulae. Participants raised their heads and trunks to an angle of 15 degrees against resistance, and the strength of this muscle group was measured. Each muscle group's strength was assessed three times, and the average of the three repetitions was recorded as the final score [23]. The tester applied sufficient force to overcome the resistance the subjects in each muscle group provided.

This study assessed muscle strength using the Bruininks-Oseretsky Test of Motor Proficiency strength sub-test, abbreviated as the BOT-2. The BOT-2 is a norm-referenced assessment tool designed to evaluate motor performance in children aged 4.5 to 14.5 years. It comprises eight sub-tests, encompassing 46 individual tasks [24]. However, only the strength sub-test was utilized for this study to measure muscle strength.

In the strength sub-test of the Bruininks-Oseretsky Test of Motor Proficiency, there were three components: the long jump test, the sit-up test, and the push-up test. Participants were directed to pull their arms back and leap forward as far as possible for the long jump test. They were encouraged to attempt to fall forward if balance

Figure 2: Some of the measuring the muscle strength

was lost during the jump. Each participant performed the test thrice, and the distance jumped on each occasion was recorded as their score (Figure 3) [24].

For the sit-up test, participants were instructed to lie on a mat with their hands placed on their femurs and their chin resting on their chest. An examiner positioned next to the participant placed a ruler on their knees. Participants were then asked to raise their trunks sufficiently to touch the ruler and return to the mat. The objective was to perform as many sit-ups as possible within a 20-second. Sit-ups executed with elbows on the floor, holding onto the mat or pants, or without touching the ruler were deemed incorrect and were not tallied. The total number of correct sit-ups completed by the participant within the allotted time was recorded as their score (Figure 4).

For the push-up test, participants assumed a prone position on a mat with their knees bent and in contact with a wall. Placing their hands next to their shoulders on the floor, participants were instructed to straighten their elbows fully, ensuring that their backs touched a ruler positioned by an examiner. They then lowered their chests to the ground, performing push-ups for 20 seconds. Push-ups were deemed incorrect if the participant's back arched and did not touch the ruler or if their hips rose above body level. The total number of correct push-ups completed within the allotted time was recorded as their score (Figure 5) [24].

After the pre-test, participants in the experimental group engaged in 8 weeks of combined turning exercises [25], with sessions lasting 45 to 60 minutes per day, conducted three times a week. Meanwhile, the control group maintained their regular activities throughout the study period. The exercises were structured according to the overload, progression, and individualization principles (Table 1).

The Shapiro-Wilk test was employed to assess the normality of data distribution. Descriptive statistics, such as mean and standard deviation, were utilized to summarize the data. Repeated measures analysis of variance (ANOVA) was employed for inferential statistics, with significance set at 0.05.

Results

The results are summarized in Tables 2 and 3. Table 2 presents the demographic characteristics of the participants, encompassing height, weight, age, and IQ.

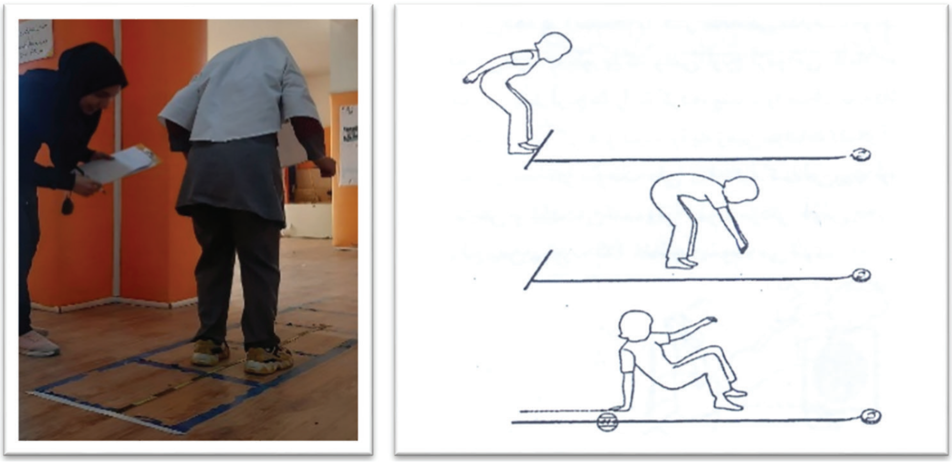

Figure 3: Long jump

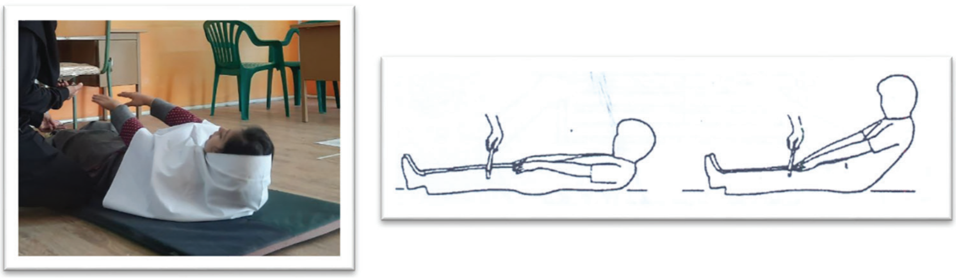

Figure 4: Sit-up test

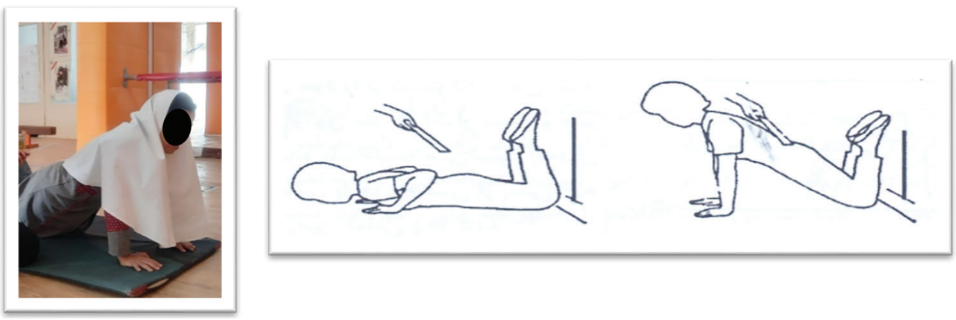

Figure 5: Push-up test

Table 1: Overview of the exercise program in the experimental group

The combined turning exercises		
Warm-up	Low-intensity aerobic exercises and range of motion (ROM)exercises	10 minutes
Resistance turning exercises	Upper limbs: chest, back, shoulder, forearm, back of arm, etc. Core stability: sit-up, bridge, plank, superman, vacuum, etc. Lower limbs: hip flexion, hip abduction, hip adduction, knee flexion, knee extension, lifting on the toe, squat, etc.	20 minutes
Standing turning exercises	1. Standing on two feet, anterior cross standing, posterior cross standing, standing heel to heel, standing on both feet and turning the head, standing on both feet and turning the trunk, standing on both feet and turning lumbar, standing on both feet and turning weight transfer, standing and turning upper body with open arms, standing on one leg, Standing with one leg turned outward, standing on one leg and turning the head, standing on one leg and turning the trunk, standing on one leg and turning lumbar, standing on one leg and turning weight transfer, standing and turning the lateral pair of feet on the heel, standing and turning the lateral pair of feet on the forefoot, toe raises internal rotation and external rotation, standing and turning one leg around the other 2. Rotate 180 degrees, rotate 270 degrees, single leg stance-clock, 90 degrees, turning the jump pair of legs and one leg, etc.	25 minutes
Walking turning exercises	Exercises in turning paths: walking, walking to the side, narrow walking, march walking, semi-tandem walking, walking on toes, tandem walking, semi-tandem walking on toes, tightrope walking, galloping, sliding, hopping, lateral walking on heel and toe, cross walking, braiding walking, dynamic walking, walking and turning the ball around the lumbar, walking backward, grapevine walking, etc.	
Cool down	Low-intensity aerobic exercises and range of motion (ROM)exercises	5 minutes

Table 2: The demographic characteristics of the participants

Factor	Group	Mean±SD	t	P
Age	Experimental	12.15±1.62	0.9	0.6
	Control	12.23±1.53		
Height	Experimental	139.23±8.94	1.1	0.1
	Control	141.15±10.31		
Weight	Experimental	42.62±13.44	1.7	0.08
	Control	45.46±15.94		
IQ	Experimental	63.02±5.54	0.85	0.7
	Control	63.05±5.49		

SD: Standard deviation; IQ: Inteligence quotient

None of the measurement factors yielded significant P values ($P<0.05$), indicating homogeneity between the groups across demographic characteristics, particularly mental performance.

Table 3 presents both descriptive statistics and the variance analysis results. The interaction term in the repeated measures analysis of variance is particularly noteworthy as it reflects the changes between the two groups over time, thereby delineating the progression. The analysis indicated a significant interaction effect for muscle strength ($P<0.05$), signifying that the changes observed in the experimental group exceeded those in the control group, with the experimental group demonstrating greater improvement.

Discussion

This study aimed to assess the impact of an eight-week combined turning exercise program on the physical performance of educable students with DS. The findings revealed a notable enhancement in muscle strength ($P<0.05$), suggesting that combined turning exercises effectively augment muscle strength among students with DS.

The exercise regimen employed in this study included resistance-turning exercises specifically targeting the upper body muscles, including the chest, back, shoulders, forearms, and triceps. These exercises are instrumental in strengthening the connective tissues surrounding the elbows, shoulders, neck, spine, wrists, and hands, enhancing joint health and stability while mitigating the risk of injuries. As evidenced by the significant improvement observed in the push-up test, participants in the experimental group demonstrated enhanced upper-body muscle strength following the intervention.

Lower body exercises are pivotal in enhancing physical endurance and overall strength. By targeting the muscles of the lower body, individuals can fortify their core, enhance range of motion, and augment strength in various muscle groups. The combined turning exercises in this study engaged the lower body muscles comprehensively, leading to notable improvements in lower limb muscle strength. Additionally, participants in the experimental group exhibited significant enhancements in the long jump test.

The strength of the trunk muscles is paramount for generating force against external resistance encountered during daily activities, underscoring the importance of maintaining optimal trunk muscle strength for overall physical fitness and efficiency [26]. In this study, the exercise regimen incorporated resistance-turning exercises targeting the core muscles, thereby contributing to trunk flexor and extensor strength improvements. Notably, participants in the experimental group demonstrated a significant enhancement in trunk muscle strength, as evidenced by their improved performance in the sit-up test.

The lack of significant progress observed in the control group underscores the notable impact of combined turning exercises on enhancing the strength—both upper, lower, and mid-body—of students with DS.

Individuals with intellectual disabilities often face barriers to engaging in regular physical activity, which can contribute to declines in cardiovascular fitness,

Table 3: General results of analysis of variance for repeated measurements of muscle strength (handheld digital dynamometer, push-up, sit-up, and long jump)

Variable		Group	Pre-test Mean±SD	Post-test Mean±SD	Intragroup changes	Group interaction	Intergroup changes	η2	Power
Elbow flexor muscles (Newton)	Right	Experimental	39.09±20.48	65.64±25.96	F=43.50 P=0.00	F=31.20 P=0.00	F=2.89 P=0.1	0.565	1
		Control	38.58±14.13	40.74±16.55					
	Left	Experimental	47.03±22.18	68.63±29.41	F=40.60 P=0.00	F=18.80 P=0.00	F=5.41 P=0.02	0.439	0.986
		Control	37.73±10.65	41.84±14.03					
Elbow extensor muscles (Newton)	Right	Experimental	39.02±18.01	53.47±21.95	F=39.28 P=0.00	F=31.04 P=0.00	F=3.57 P=0.07	0.546	1
		Control	33.84±13.18	34.69±10.36					
	Left	Experimental	34.35±16.15	35.95±23.36	F=34.67 P=0.00	F=25.39 P=0.00	F=3.28 P=0.08	0.514	0.998
		Control	32.15±12.59	33.67±10.90					
Arm adductor muscles (Newton)	Right	Experimental	27.41±9.09	33.98±7.20	F=62.36 P=0.00	F=28.16 P=0.00	F=0.35 P=0.55	0.54	0.999
		Control	28.75±12.85	30.63±13.12					
	Left	Experimental	26.73±8.22	35.20±9.33	F=76.81 P=0.00	F=26.49 P=0.00	F=0.02 P=0.88	0.525	0.999
		Control	29.27±10.97	31.47±12.61					
Arm abductor muscles (Newton)	Right	Experimental	27.75±8.77	42.30±14.87	F=27.76 P=0.00	F=9.74 P=0.00	F=3.18 P=0.08	0.289	0.85
		Control	26.23±7.26	29.95±10.98					
	Left	Experimental	26.40±7.82	41.46±14.50	F=28.09 P=0.00	F=17.89 P=0.00	F=4.78 P=0.03	0.427	0.982
		Control	25.55±7.38	27.24±6.87					
Hip flexor muscles (Newton)	Right	Experimental	69.64±28.38	112.32±41.70	F=26.95 P=0.00	F=20.60 P=0.00	F=5.82 P=0.02	0.462	0.992
		Control	62.40±26.66	65.26±23.13					
	Left	Experimental	56.84±23.21	99.13±33.90	F=33.43 P=0.00	F=26.63 P=0.00	F=3.90 P=0.06	0.526	0.999
		Control	57.50±23.25	59.90±25.19					
Hip extensor muscles (Newton)	Right	Experimental	48.21±19.66	75.24±26.71	F=76.12 P=0.00	F=48.41 P=0.00	F=6.93 P=0.01	0.669	1
		Control	41.63±10.94	44.76±12.29					
	Left	Experimental	46.35±21.37	70.07±26.96	F=43.92 P=0.00	F=41.59 P=0.00	F=6.95 P=0.01	0.634	1
		Control	39.60±10.55	39.92±11.52					
Hip abductor muscles (Newton)	Right	Experimental	42.98±19.02	68.47±27.44	F=96.67 P=0.00	F=46.83 P=0.00	F=5.42 P=0.02	0.661	1
		Control	36.04±12.71	40.61±15.28					
	left	Experimental	38.92±14.35	71.01±35.34	F=26.08 P=0.00	F=11.57 P=0.00	F=6.78 P=0.01	0.325	0.904
		Control	32.32±10.60	38.75±15.77					
Knee flexor muscles (Newton)	Right	Experimental	43.66±18.29	67.78±28.16	F=37.32 P=0.00	F=21.54 P=0.00	F=4.56 P=0.04	0.473	0.994
		Control	39.09±10.59	42.38±13.03					
	left	Experimental	43.21±21.90	65.27±36.03	F=29.09 P=0.00	F=14.71 P=0.00	F=3.09 P=0.09	0.38	0.957
		Control	37.56±10.25	41.29±10.51					
Trunk extensor muscles (Newton)		Experimental	51.44±18.35	77.81±23.88	F=86.06 P=0.00	F=51.48 P=0.00	F=5.37 P=0.02	0.682	1
		Control	45.87±16.85	49.24±16.88					
Trunk flexor muscles (Newton)		Experimental	43.83±17.19	65.66±19.83	F=42.91 P=0.00	F=22.45 P=0.00	F=9.04 P=0.00	0.481	0.995
		Control	36.21±9.98	39.76±10.75					
Push-up (Second)		Experimental	1±0.91	7.46±2.72	F=126.42 P=0.00	F=90.51 P=0.00	F=38.73 P=0.00	0.79	1
		Control	0.77±0.72	1.31±0.75					
Sit-up (Second)		Experimental	2.69±2.23	11.69±3.47	F=156 P=0.00	F=99.84 P=0.00	F=35.98 P=0.00	0.806	1
		Control	1.77±1.23	**2.77**±1.64					
Long jump (Centimeter)		Experimental	49.30±11.49	63.46±16.18	F=31.45 P=0.00	F=17.22 P=0.00	F=2.07 P=0.00	0.418	0.978
		Control	46.65±17.95	48.77±16.79					

Significance at P≤0.05. η^2: Partial eta squared

muscle strength, speed, and overall physical fitness levels [27]. Moreover, the inherent challenges associated with intellectual disabilities may predispose individuals to lower flexor and extensor strength and endurance levels in the trunk muscles. These deficits can adversely affect coordination during complex movements and impede this population's development of motor skills [28].

The utilization of turning exercises represents this study's significant and innovative aspect. Turning, an integral aspect of mobility [29] and daily activities [30], poses greater challenges than straightforward walking [31-34] and engages multiple limbs and joints. By incorporating turning components and multi-planar movements, turning exercises offer a more demanding and impactful training regimen than conventional exercises. Moreover, the resemblance of turning movements to daily movement patterns enhances their transferability to real-life scenarios [18].

Turning training necessitates coordination across various bodily systems and processes due to its complexity, requiring higher levels of sensory-motor integration and cognitive engagement. This multifaceted nature of turning exercises elicits greater compatibility and adaptive responses from training individuals [35]. Moreover, turning exercises demand intricate coordination of whole-body movements and the integration of multiple sensory systems to meet the heightened balance requirements [36].

Furthermore, turning exercises entail the complex control of trunk movements alongside asymmetric lower limb movements. Compared to straight walking, turning necessitates a series of neural processes to achieve stability and regulate forward progress effectively [33]. Consequently, impairments in balance, postural stability, flexibility, strength, trunk mobility, and coordination can impact an individual's ability to perform turning movements effectively [37].

The research underscores the efficacy of multi-component exercise interventions in enhancing physical performance. Turning training, including turning components and multi-planar movements, is more effective than traditional training methods. The resemblance of turning movements to everyday movement patterns enhances their transferability, making them more applicable to real-life situations [18].

Multi-plane exercises, such as turning, have been associated with greater enhancements in neuromuscular integration, stability, and functional transfer compared to linear or single-plane movements [19]. The complexity of turning exercises physically and cognitively challenges individuals, promoting increased brain activation, muscle coordination, and cortical reorganization. These adaptations ultimately lead to improvements in overall physical performance [20].

The exercise regimen implemented in this study specifically targeted muscle strength enhancement, aiming to mitigate muscle hypotonia commonly observed in individuals with DS. In the experimental group, various multi-plane exercises were employed to train different muscle groups of the upper limbs, aligning with the muscles assessed in both the push-up test and the dynamometer's evaluations. These exercises encompassed the elbow flexors, extensors, abductors, and arm adductors. Consequently, significant improvements in upper body muscle strength were observed, as evidenced by the test progress and the significant interaction in this muscle group.

Furthermore, the resistance training program also focused on bolstering core stability by targeting the muscles associated with trunk flexion and extension, which were evaluated through the sit-up test and dynamometer assessments.

Hence, notable advancements were evident in the assessments, along with a notable enhancement in the strength of the core stability muscles. The third component of the multi-plane resistance exercises and turning routines targeted the lower extremities, engaging muscle groups assessed in the long jump test and those evaluated by the dynamometer (comprising hip flexors, hip extensors, hip adductors, and knee flexors). Consequently, improvements in the assessments and a significant enhancement in lower limb strength were apparent. These findings underscore the impact of combined turning exercises on muscle strength among students diagnosed with DS.

This study has several limitations, including a limited sample size exclusively comprising females, a lack of follow-up assessments after the post-test to ascertain the sustainability of the observed outcomes, and an absence of prior research exploring the effectiveness of turning exercises, hindering comparison and generalization. Consequently, future research should aim to include participants of both genders and incorporate long-term follow-up assessments to address these limitations comprehensively.

Conclusion

The findings revealed a notable enhancement in muscle strength ($p < 0.05$), suggesting that combined turning exercises effectively augment muscle strength among students with DS. The results of this investigation imply that incorporating combined turning exercises could serve as an effective strategy for enhancing muscle strength among female students diagnosed with DS. Integrating these exercises into rehabilitation programs tailored for individuals with DS may improve their physical performance and enhance their overall quality of life.

Acknowledgment

We would like to express our gratitude to Education Department of Isfahan Province, all the subjects and their families who helped us in conducting this study.

Conflict of Interest: None declared.

References

1. Torr J, Strydom A, Patti P, Jokinen N. Aging in Down syndrome: morbidity and mortality. Journal of Policy and Practice in Intellectual Disabilities. 2010;7(1):70-81.
2. Moore G, Durstine JL, Painter P, Medicine ACoS. Acsm's exercise management for persons with chronic diseases and disabilities, 4E: Human Kinetics; 2016.
3. Cabeza-Ruiz R, García-Massó X, Centeno-Prada R, Beas-Jiménez J, Colado J, González L-M. Time and frequency analysis of the static balance in young adults with Down syndrome. Gait & posture. 2011;33(1):23-8.
4. Wu J, Ulrich DA, Looper J, Tiernan CW, Angulo-Barroso RM. Strategy adoption and locomotor adjustment in obstacle clearance of newly walking toddlers with Down syndrome after different treadmill interventions. Experimental Brain Research. 2008;186(2):261-72.
5. El-Meniawy GH, Kamal HM, Elshemy SA. Role of treadmill training versus suspension therapy on balance in children with Down syndrome. Egyptian Journal of Medical Human Genetics. 2012;13(1):37-43.
6. Berg P, Becker T, Martian A, Danielle PK, Wingen J. Motor control outcomes following Nintendo Wii use by a child with Down syndrome. Pediatric Physical Therapy. 2012;24(1):78-84.
7. Bahiraei S, Daneshmandi H. The Study of relationship between structural profiles and postural control in individual with Down syndrome. Journal of Practical Studies of Biosciences in Sport. 2014;2(4):21-32.
8. Eid MA, Aly SM, Huneif MA, Ismail DK. Effect of isokinetic training on muscle strength and postural balance in children with Down's syndrome. International Journal of Rehabilitation Research. 2017;40(2):127-33.
9. Borji R, Zghal F, Zarrouk N, Sahli S, Rebai H. Individuals with intellectual disability have lower voluntary muscle activation level. Research in developmental disabilities. 2014;35(12):3574-81.
10. Yu C, Li J, Liu Y, Qin W, Li Y, Shu N, et al. White matter tract integrity and intelligence in patients with mental retardation and healthy adults. Neuroimage. 2008;40(4):1533-41.
11. Graham A, Reid G. Physical fitness of adults with an intellectual disability: A 13-year follow-up study. Research quarterly for exercise and sport. 2000;71(2):152-61.
12. Mashhadi M, Ghasemi G, Zolaktaf M. The Effect of selected exercise training on thoracic kyphosis and lumbar lordosis of adolescents with mental retardation. Journal of research rehabilitation. 2012;8(1):192-201.
13. Naczk A, Gajewska E, Naczk M. Effectiveness of swimming

program in adolescents with down syndrome. International journal of environmental research and public health. 2021;18(14):7441.
14. Barnard M, Swanepoel M, Ellapen TJ, Paul Y, Hammill HV. The health benefits of exercise therapy for patients with Down syndrome: A systematic review. African journal of disability. 2019;8(1):1-9.
15. Giagazoglou P, Kokaridas D, Sidiropoulou M, Patsiaouras A, Karra C, Neofotistou K. Effects of a trampoline exercise intervention on motor performance and balance ability of children with intellectual disabilities. Research in developmental disabilities. 2013;34(9):2701-7.
16. Gupta S, Rao BK, Kumaran S. Effect of strength and balance training in children with Down's syndrome: a randomized controlled trial. Clinical rehabilitation. 2011;25(5):425-32.
17. Bahiraei S, Daneshmandi H, Sedaghati P. The effect of a selective combined training program on motor performance, balance and muscle strength in boys with Down Syndrome (DS). Journal of Paramedical Sciences & Rehabilitation. 2017;6(4):40-5.
18. Jadczak AD, Makwana N, Luscombe-Marsh N, Visvanathan R, Schultz TJ. Effectiveness of exercise interventions on physical function in community-dwelling frail older people: an umbrella review of systematic reviews. JBI Evidence Synthesis. 2018;16(3):752-75.
19. Patel K, Wilkinson N. Corrective Exercise: A Practical Approach: A Practical Approach: Routledge; 2014.
20. Chen I-H, Yang Y-R, Chan R-C, Wang R-Y. Turning-based treadmill training improves turning performance and gait symmetry after stroke. Neurorehabilitation and neural repair. 2014;28(1):45-55.
21. Yousefi M, Eelbeigi S, Mehrshad N, Afzalpoor M. Detection of spinal abnormalities using markers mounted on the spine appendages. Sports medicine. 2011;4:73-89.
22. Bohannon R. Hand-held compared with isokinetic dynamometry for measurement of static knee extension torque (parallel reliability of dynamometers). Clinical Physics and Physiological Measurement. 1990;11(3):217.
23. Arnold CM, Warkentin KD, Chilibeck PD, Magnus CR. The reliability and validity of handheld dynamometry for the measurement of lower-extremity muscle strength in older adults. The Journal of Strength & Conditioning Research. 2010;24(3):815-24.
24. Bruininks RH, Bruininks BD. Bruininks-Oseretsky test of motor proficiency. 1978.
25. Ghaderian M, Ghasemi GA, Lenjannejadian S, Demneh ES. The Effect of Turning Training in Comparison with Balance Training on Balance Performance, Mobility, Turning and Fear of Falling in Older Adults1. Studies in Sport Medicine. 2022;14(32):43-76.
26. Arampatzis A, Frank J, Laube G, Mersmann F. Trunk muscle strength and lumbo-pelvic kinematics in adolescent athletes: Effects of age and sex. Scandinavian journal of medicine & science in sports. 2019;29(11):1691-8.
27. Hosseini-Kakhk SA, Nasrabadi S, Haghighi A-H, Sharifi-Moghadam A. The effect of combined exercise training program on some physical fitness factors in mentally retarded girls. Journal of Practical Studies of Biosciences in Sport. 2018;6(11):109-20.
28. Kong Z, Sze T-M, Yu JJ, Loprinzi PD, Xiao T, Yeung AS, et al. Tai Chi as an alternative exercise to improve physical fitness for children and adolescents with intellectual disability. International journal of environmental research and public health. 2019;16(7):1152.
29. Berg K, Wood-Dauphine S, Williams J, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. Physiotherapy Canada. 1989;41(6):304-11.
30. Glaister BC, Bernatz GC, Klute GK, Orendurff MS. Video task analysis of turning during activities of daily living. Gait & posture. 2007;25(2):289-94.
31. Segal AD, Orendurff MS, Czerniecki JM, Shofer JB, Klute GK. Local dynamic stability in turning and straight-line gait. Journal of biomechanics. 2008;41(7):1486-93.
32. Courtine G, Schieppati M. Human walking along a curved path. I. Body trajectory, segment orientation and the effect of vision. European Journal of Neuroscience. 2003;18(1):177-90.
33. Orendurff MS, Segal AD, Berge JS, Flick KC, Spanier D, Klute GK. The kinematics and kinetics of turning: limb asymmetries associated with walking a circular path. Gait & posture. 2006;23(1):106-11.
34. Boelen MP. Health Professionals' Guide to Physical Management of Parkinson's Disease: Human Kinetics; 2009.
35. Brahms CM, Hortobágyi T, Kressig RW, Granacher U. The interaction between mobility status and exercise specificity in older adults. Exercise and sport sciences reviews. 2021;49(1):15-22.
36. Cheng F-Y, Yang Y-R, Wu Y-R, Cheng S-J, Wang R-Y. Effects of curved-walking training on curved-walking performance and freezing of gait in individuals with Parkinson's disease: a randomized controlled trial. Parkinsonism & related disorders. 2017;43:20-6.
37. Khobkhun F, Khacharoen S, Tretriluxana J, Richards J. The effectiveness of exercise on gait, turning and falls in individuals with Parkinson's disease: A Scoping Review. International Journal of Pharmaceutical Research. 2021;13(2).