SCIENTIFIC PAPERS PUBLICATION ABOUT BENEFITS OF ADAPTED JUDO PRACTICE ON CHILDREN WITH ASD

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ORIGINAL ARTICLE

Inter-rater reliability of a classification system for athletes with intellectual disabilities in adapted judo competitions

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background and Study Aim: The proliferation of adapted judo programs for people with intellectual disabilities has garnered continuous growth in the number of participants in this activity. As a result of this growing popularity, a number of adapted international judo competitions are now being held. The adaptive judo classification system was established to ensure that Special Needs judo athletes could be appropriately divided into categories to ensure their safety within the context of competition. The purpose of this study is knowledge about the reliability of the recently developed classification system for individuals with intellectual disabilities in adapted judo competitions.

Material and Methods: The classification system has five levels according to functional criteria. Six raters (experts) evaluated 20 videos of official adapted judo competitions, corresponding to one of the five proposed classification categories. Two methods were used to quantify the degree of inter-rater agreement as to the analysis and classification of the recorded matches. Inter-rater agreement was evaluated using the Intraclass Correlation Coefficient (ICC) and Fleiss-Kappa procedures.

Results: Results indicated an excellent degree of inter-rater reliability, showing that the system produces consistent results with different raters.

Conclusions: This study represents an important step forward in the classification level of participants in adapted judo competitions for people with intellectual disabilities. Future international adapted judo competitions would benefit from field studies to confirm the reliability of this classification system.

Keywords: autism spectrum disorder • down syndrome • Paralympian • special needs judoka • Special Olympics World Games

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Conflict of interest: Authors have declared that no competing interest exists

Ethical approval: The study was approved by the local research ethics committee. All the research protocols used in this study are in compliance with the requirements set out in the 1975 Helsinki declaration and the subsequent revisions of this document

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INTRODUCTION

Intellectual disability – psychological or mental state limiting the various forms of activity performed by an individual.

ASD – autism spectrum disorder is a neurodevelopmental disorder characterized by a variety of symptoms that impact social and behavioural functioning.

Stereotypic behaviour – repetitive, invariant behaviour pattern with no obvious goal or function.

Adapted judo – judo practice that includes modifications of the objectives, methods and contents of teaching judo to children with disabilities.

Kata – prescribed patterns or sequences of techniques [34].

Paralympian – *noun* an athlete who competes in the Paralympics [35].

The positive effects of physical and athletic activity on the overall health of young people with intellectual disabilities (ID) have been well documented [1]. In broad terms, the positive effects can be grouped into two areas. Firstly, there are benefits for physical health, including improvements in physical aptitudes and bone metabolism, an increase in the performance of cardiovascular and respiratory muscles, and decreases in the likelihood of obesity and a sedentary lifestyle. Secondly, there are psychosocial effects, which can include greater functional independence and fuller inclusion in social activities, as well as cognitive benefits and increases in various aspects of psychological wellbeing (especially in terms of self-esteem, self-competence and positive self-perception) [2]. Despite this evidence, a number of studies nonetheless show that people with mental disabilities tend to spend much less time than others on physical activity [3], and that these individuals tend to be in worse physical health than the population on average [4] and are more likely to be obese [5]. For these reasons, it is highly desirable to develop and implement exercise or sports programs and other educational strategies to help people with ID to improve their overall health and to motivate them to take part in regular physical activity.

Recent research involving sports, such as soccer [6], tennis [7] and baseball [8], highlight adapted sport and exercise programs developed with the aim of helping individuals with ID improve their quality of life. Meanwhile, a number of systematic reviews and meta-analyses have measured the positive effects that physical exercise and participation in sports programs including swimming, track and team sports can have for this population [2, 8-10]. In terms of the type of ID, these studies predominantly focus on individuals with down syndrome (DS) or autism spectrum disorder (ASD), while a lesser number of researchers have also examined individuals with Prader-Willi Syndrome [1].

Several studies have also provided evidence of the benefits offered by participation in martial arts programs that are adapted to meet the needs of individuals with ID [11]. Research has shown these programs to be especially effective at improving the motor skills of people with ASD [12, 13] and DS [14]. These activities have also proven to have psychosocial benefits, with karate katas aimed at people with ASD, for example, having been shown to lead to significant improvements in stereotypical behaviours and social interaction [15, 16]. The characteristics of martial arts make them well suited to the individuals with ID because of their use of moderate to vigorous exercise intensities and the added mental components of concentration and self-control [17]. Martial arts can also be appealing to young people with ASD because of the repetitive nature of the exercises involved [18]. Recent research into the effects of judo participation on children with ASD has yielded promising initial results, particularly psychosocial benefits, such as increases in both social skills and self-esteem [19]. Participants have also tended to engage in moderate to strenuous physical activity more often and to reduce the time they spend on sedentary behaviour [17].

The proliferation of adapted judo programs for people with ID has garnered continuous growth in the number of participants in this activity. As a result of this growing popularity, a number of adapted judo competitions are now being held. Institutions such as the Special Needs Judo Union (SNJU) and the Special Olympics have led the way in organizing a growing number of competitive opportunities for individuals with ID.

The rules governing these events have evolved and improved over time, with organizers striving to guarantee the safety of all the athletes who take part. In 2018, the revised rulebook was released after two years of testing. This update was developed by international experts in adaptive judo in conjunction with experienced adaptive judo referees and coaches from various countries across Europe. In the past two years (2018-2020), these

rules were used in all major national and international adaptive judo tournaments, including the Special Olympics World Games.

The regulations are now applied by adapted judo associations in 28 different countries [20] and 46 Special Olympic countries & territories worldwide [21].

With the aim of establishing worldwide standards for adapted judo events, the same rule set of the SNJU rules [20] have been adopted by Special Olympic International in their 2020 updates [21]. The rules currently in place classify participants into five categories based on their skill level. This is distinct from the mainstream classification system, which places participants according to their age and weight class. The technical rules and the scoring system used in the adapted competitions are very similar to those of the International Judo Federation, with some minor adaptations aimed at further ensuring the participants' safety.

The purpose of this study is knowledge about the reliability of the recently developed classification system for individuals with intellectual disabilities in adapted judo competitions.

MATERIAL AND METHODS

Methodology

This study consisted of two methodological phases. The first took the form of an application of the Delphi technique [22] in order to assess the validity of the proposed classification system. Six experienced experts offered their evaluation as to the classification of athletes with ID in adapted judo competitions. The resulting classifications were applied at different competitions, and the experts used the feedback obtained from the events to inform a series of changes to their criteria. They repeated this process until they had come to a consensus. The second phase consisted of an inter-rater reliability test aimed at measuring the degree of agreement between observers applying the consensus classification system. To accomplish this, the raters viewed a number of video recordings of judo bouts from adapted judo competitions.

Participants

Six raters (five men and one woman) took part in the classification process. Each of them had at least four years of experience working with judo athletes with ID. Three of the raters were internationally certified referees with experience classifying tournament participants, and the other three were adapted judo coaches who had taken part in international competitions. The raters watched 20 videos of official adapted judo competitions, with each recorded match corresponding to one of the five proposed classification categories.

Classification protocol and assignment to categories

The adaptive judo classification system was established to ensure that special needs judo athletes could be appropriately divided into categories to ensure their safety within the context of competition. The classification system has five levels 1 to 5, with 1 representing the highest ability level and 5 indicating the lowest ability level.

The levels are determined according to functional criteria. The raters compare the skill level of the special needs judoka with that of typically-developed competitive judoka (for level 1) or that of typically-developed recreational judoka (levels 2-5). The SNJU classification system for adapted judo tournaments [20] is presented in Table 1.

Data collection procedure

All of the judo matches were video recorded from the same angle in order to ensure that the participants' movements were clearly visible. The length of each recording was limited to the beginning of the first minute in order to force the raters to issue a judgement under conditions even more demanding than they would likely face in real life.

Prior to the data collection process, the expert raters reviewed the SNJU classification criteria (2018) that have been adopted by the Special Olympics (2020). A multiple choice, video-based Moodle system (with users able to choose from five options) was developed to allow the raters to watch the adapted judo match recordings and provide an assessment of the corresponding level of the judoka. Twenty videos in total were presented, showing matches at varying levels (from 1 to 5) (level 1: n = 3, level 2: n = 2, level 3: n = 7, level 4: n = 5, level 5: n = 3).

Statistical analysis

Two methods were used to quantify the degree of inter-rater agreement as to the analysis and classification of the recorded matches. Inter-rater agreement was evaluated using the intraclass

Table 1. Classification system proposed for Special Needs Judo Union (2018) and adopted for Special Olympics (2020).

Level 1 is a judoka who can perform in a contest with a typical developed competitive judoka. This judoka is fast and powerful and has excellent reactivity. He/she has a strong feeling for Judo and an excellent strategic view. This type of judoka has a minimal disability and therefore usually attends regular education. In general, these are judoka with high functioning autism or light physical disability, as well as hearing impaired judokas and some judoka with ID that have progressed beyond level 2.
Level 2 is a judoka who can perform randori with typical developed recreational judoka. This judoka is fast and powerful and has moderate reactivity but is usually slow to respond to judo situations. He/she has good judo feeling, but usually no effective strategy.
Level 3 is a judoka who can perform a playful randori with typical developed recreational judoka. This judoka is reasonably fast and powerful and has reasonably developed reactivity, but is almost always slow responding to situational judo. Strategy for this type of judoka consists of repeating the same technique over and over.
Level 4 is a judoka who can grapple and play with another judoka of the same or comparable level. Reactivity is suboptimal. Usually the only judo technique consists of takedown and immobilize.
Level 5 is a judoka who can grapple and play with other judoka of the same level. These judokas are very passive, or respond very slowly. Constant coaching to take action is necessary. When they end up in osae-komi, the action to escape can take a very long time.

Table 2. Classification level assessments of the recorded judo matches by each rater.

Match	Rater						Level allocation
	1	2	3	4	5	6	
1	4	4	5	4	4	4	4
2	4	5	4	5	4	5	5
3	4	4	4	4	4	4	4
4	2	3	3	3	3	3	3
5	1	2	1	1	1	1	1
6	1	2	2	2	2	2	2
7	5	5	4	5	5	5	5
8	1	1	1	1	1	1	1
9	3	3	3	3	3	3	3
10	3	3	3	3	3	3	3
11	5	5	5	5	5	5	5
12	4	3	4	3	4	4	4
13	4	4	4	4	4	4	4
14	3	2	3	3	3	3	3
15	2	2	2	1	1	1	1
16	4	3	3	4	4	4	4
17	2	2	2	2	2	2	2
18	3	3	2	2	3	3	3
19	3	3	3	3	3	3	3
20	2	3	3	3	3	3	3

correlation coefficient (ICC) and Fleiss-Kappa procedures. The ICC (model 2, 1) was interpreted such that >0.8 = excellent, 0.7-0.8 = good, 0.5-0.7 = fair, <0.5 = poor [23]. The standard error of measurement (SEM) was calculated as SEM = SD × √(1-ICC) [24]. Following Landis and Koch [25], Fleiss Kappa was interpreted such that a Kappa value <0.0 = poor agreement, 0.0-0.2 = slight agreement, 0.2-0.4 = fair agreement, 0.4-0.6 = moderate agreement, 0.6-0.8 = substantial agreement, and 0.8-1 = near perfect agreement. Confidence intervals (CI) of 95% are reported with the ICC and Fleiss Kappa values. Statistical analyses were performed using SPSS software v.24 (SPSS Inc., Chicago, IL, USA).

RESULTS

The six raters displayed excellent agreement in their level assessments of the recorded judo matches with an ICC value of 0.91, (CI of 95%, 0.84 to 0.95, p <0.001) and SEM of 0.36. Table 2 shows the raters' classifications for each of the bouts.

The Fleiss Kappa values for classification level assessments within raters reflected agreement between substantial and nearly perfect, with a mean percentage of agreement of 85% (Table 3).

The Fleiss Kappa values for classification level assessments indicated at least substantial agreement (with the proportions of agreement reaching at least 77.77%) (Table 4), with the exception of the level 2 judo matches.

DISCUSSION

The high level of agreement between the raters is reflected in the ICC calculation, which yielded a figure of 0.91. This indicates an excellent degree of inter-rater reliability, showing that the system produces consistent results with different raters. The fact that the levels of inter-rater reliability found in this study were so high is especially significant given that the video recordings used were only one-minute long. This limited opportunity for observation might have been an obstacle to the classification, and such a limitation would not be an issue under normal circumstances. However, the fact that the raters were able to observe judo matches meant that they could analyse two participants at once. This provided them with additional context to inform their classification level assessments.

The Fleiss Kappa values indicated that the agreement among all the raters ranged from substantial to nearly perfect, with an average value of

Table 3. Intra-rater and overall agreement values.

Statistic indicator	Rater						Overall
	1	2	3	4	5	6	
Fleiss Kappa (95% CI)	0.67 (0.41-1.03)	0.67 (0.43-1.05)	0.60 (0.39-0.97)	0.87 (0.54-1.20)	0.93 (0.52-1.08)	1 (0.76-1.24)	0.79 (0.52-1.22)
% agreement	80%	75%	70%	90%	95%	100%	85%

Table 4. Classification level and overall assessment agreement values.

Statistic indicator	Level					Overall
	1	2	3	4	5	
Fleiss Kappa (95% CI)	0.71 (0.59-0.82)	0.49 (0.38-0.60)	0.71 (0.59-0.82)	0.68 (0.56-0.79)	0.71 (0.59-0.82)	0.66 (0.60-0.72)
% agreement	77.77%	91.66%	90.47%	83.33%	83.33%	85%

0.79. One possible explanation for the high level of inter-rater reliability found here is the fact that this classification system has already been in use for a few years in unofficial competitions and exhibition matches. In other words, the referees and coaches who are responsible for applying these standards are already familiar with them. Earlier studies [26] have found that the inter-rater reliability of tests measuring athletes' functional skills tends to increase when the raters have more training and experience. Our study further confirms this, as the raters who displayed the greatest degree of agreement were those with the most experience and those who were certified referees. The latter are responsible for classifying athletes prior to competitions. In light of this, it is clear that future raters should be given practical training in order to ensure they have the experience they need.

A number of prior studies have examined the validity and reliability of a range of different classification methods for athletes in adapted sports [27-31]. The level of agreement reflected in this study by the Fleiss Kappa values for the assignment to classification levels was not as high as it was for the raters, but it was nonetheless considerable. All the classification levels showed a substantial degree of agreement (0.6-0.8) with the exception of level 2, where the figure was 0.49, indicating only moderate agreement. However, this was the category that showed the highest percentage of overall agreement (91.66%). This discrepancy between the low Fleiss Kappa value and the high overall agreement is likely due to the fact that this category was the least represented in the sample (only two bouts). A study by Rosén et al. [31] on the reliability of a classification system for Paralympians in a sport called *Para Va'a* reached a similar conclusion. This study found that tests with a lesser prevalence of cases yielded lower values, thus providing evidence that Fleiss Kappa statistics are affected by the number of cases in each category [32].

As indicated above, adapted judo athletes are placed into five classification levels based on the assessment of raters. The results of this study can be approached as nominal variables in that each level corresponds with an independent category, but they can also be taken as ordinal, in that each level represents a progression with respect to development of specific judo skills. The method used here to assess inter-rater reliability is a way to quantify the degree of agreement among a group of raters who independently analyze and score a group of participants [33]. More specifically, this study has used both ICC and the Fleiss-Kappa calculations, in order to establish the level of agreement between the raters and to analyze the data collected. The fact that the ICC calculations yielded higher values than the Fleiss-Kappa can be explained by the kind of data used in this study. The Fleiss-Kappa test is better suited to use with nominal variables such as data collected using a Likert scale, while the ICC is more effective with ordinal data [33]. Therefore, it is possible to conclude that the ICC test is the best fit when it comes to making inferences about the agreement between raters, while the Fleiss Kappa also allows us to analyse the agreement attained within each classification level.

CONCLUSIONS

This study represents an important step forward in the classification level of participants in adapted judo competitions for people with ID. The study found high levels of inter-rater reliability using different agreement analysis methods of scores assigned to video recorded matches by expert raters. Future international adapted judo competitions would benefit from field studies to confirm the reliability of this classification system.

HIGHLIGHTS

The safety of participants in sports competitions for people with intellectual disabilities is essential. This study confirms that the classification system for people with intellectual disabilities in judo competitions that is currently being used is valid and reliable.

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REFERENCES

1. Kapsal NJ, Dicke T, Morin AJS et al. Effects of physical activity on the physical and psychosocial health of youth with Intellectual disabilities: A systematic review and meta-Analysis. J Phys Act Health 2019; 16(12): 1187-1195
2. Scifo L, Chicau Borrego C, Monteiro D et al. Sport intervention programs (SIPs) to improve health and social inclusion in people with intellectual disabilities: A systematic review. J Funct Morphol Kinesiol 2019; 4(3): 57
3. Jung J, Leung W, Schram BM et al. Meta-analysis of physical activity levels in youth with and without disabilities. Adapt Phys Activ Q 2018; 35(4): 381-402
4. Oppewal A, Hilgenkamp TIM, van Wijck R et al. Cardiorespiratory fitness in individuals with intellectual disabilities—a review. Res Dev Disabil 2013; 34(10): 3301-3316
5. McConkey R, Sadowsky M, Shellard A. An international survey of obesity and underweight in youth and adults with intellectual disabilities. J Intellect Dev Dis 2019; 44(3): 374-382
6. Ryuh Y, Choi P, Oh J et al. Impact of Inclusive Soccer Program on Psychosocial Development of Children with and without Intellectual Disabilities. J Dev Phys Disabil 2019; 31(5): 691-705
7. Favoretto L, Hutchison Z, Mowling CM et al. Improvements in tennis skills in adults with developmental and intellectual disabilities following an 8-week adapted tennis program. J Motor Learn Dev 2020; 8(2): 245-261
8. Cunningham GB, Warner S. Baseball 4 All: Providing Inclusive Spaces for Persons with Disabilities. J Glob Sport Manage 2019; 4(4): 313-330
9. Bondár RZ, di Fronso S, Bortoli L et al. The effects of physical activity or sport-based interventions on psychological factors in adults with intellectual disabilities: a systematic review. J Intellect Disabil Res 2020; 64(2): 69-92
10. Thomson A, Bridges S, Corrins B et al. The impact of physical activity and sport programs on community participation for people with intellectual disability: A systematic review. J Intellect Dev Disabil 2020; 1-11
11. Masleša S, Videmšek M, Karpljuk D. Motor abilities, movement skills and their relationship before and after eight weeks of martial arts training in people with intellectual disability. Acta Gymnica 2012; 42(2): 15-26
12. Kim Y, Todd T, Fujii T et al. Effects of Taekwondo intervention on balance in children with autism spectrum disorder. J Exerc Rehabil 2016; 12(4): 314-319
13. Sarabzadeh M, Azari BB, Helalizadeh M. The effect of six weeks of Tai Chi Chuan training on the motor skills of children with Autism Spectrum Disorder. J Bodyw Mov Ther 2019; 23(2): 284-90
14. Carter K, Horvat M. Effect of Taekwondo Training on Lower Body Strength and Balance in Young Adults with Down Syndrome. J Pol Pract Intellect Disabil 2016; 13(2): 165-172
15. Bahrami F, Movahedi A, Marandi SM et al. Kata techniques training consistently decreases stereotypy in children with autism spectrum disorder. Res Dev Disabil 2012; 33(4): 1183-1193
16. Movahedi A, Bahrami F, Marandi SM et al. Improvement in social dysfunction of children with autism spectrum disorder following long term Kata techniques training. Res Autism Spect Dis 2013; 7(9): 1054-1061
17. Garcia JM, Leahy N, Rivera P et al. Brief Report: Preliminary Efficacy of a Judo Program to Promote Participation in Physical Activity in Youth with Autism Spectrum Disorder. J Autism Dev Disord 2019; 50(4): 1418-1424
18. Bell A, Palace K, Allen M et al. Using Martial Arts to Address Social and Behavioral Functioning in Children and Adolescents With Autism Spectrum Disorder. Ther Recr J 2016; 50(2): 176-181
19. Rivera P, Renziehausen J, Garcia JM. Effects of an 8-Week Judo Program on Behaviors in Children with Autism Spectrum Disorder: A Mixed-Methods Approach. Child Psychiatry Hum Dev 2020; 51(5): 734-741
20. Special Needs Judo Union. Rules for Special Needs Judo 2018 [accessed 2020 Dec 04]. Available from: URL:https://snju.org/rules-and-regulations-for-special-needs-judo-2017-english/
21. Special Olympics. Sport Rules 2020; 1–9 [accessed 2020 Dec 04]. Available from: URL:https://resources.specialolympics.org/sports-essentials/sports-and-coaching/judo?_ga=2.253857800.1893156716.1601627461-134918636.1596443713
22. Hsu C-C, Sandford BA. The Delphi technique: making sense of consensus. Pract Assessment Res Eval 2007; 12(10): 1-8
23. Blacker D, Endicott J. Psychometric properties: concepts of reliability and validity. In: Rush AJ, Pincus HA, First MB et al. editors. Handbook of psychiatric measures. Washington: American Psychiatric Association; 2002
24. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res 2005; 19(1): 231-240
25. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977; 33(1): 159-174
26. Escolar DM, Henricson EK, Mayhew J et al. Clinical evaluator reliability for quantitative and manual muscle testing measures of strength in children. Muscle Nerve 2001; 24(6): 787-793
27. Pernot HFM, Lannem AM, Geers RPJ et al. Validity of the test–table–test for Nordic skiing for classification of Paralympic sit-ski sports participants. Spinal Cord 2011; 49(8): 935-941
28. Tweedy SM, Vanlandewijck YC. International Paralympic Committee position stand—background and scientific principles of classification in Paralympic sport. Br J Sports Med 2011; 45(4): 259-269
29. Altmann VC, Groen BE, Van Limbeek J et al. Reliability of the revised wheelchair rugby trunk impairment classification system. Spinal Cord 2013; 51(12): 913-918
30. Connick MJ, Beckman E, Deuble R et al. Developing tests of impaired coordination for Paralympic classification: normative values and test–retest reliability. Sport Eng 2016; 19(3): 147-154
31. Rosén JS, Goosey-Tolfrey VL, Tolfrey K et al. Interrater Reliability of the New Sport-Specific Evidence-Based Classification System for Para Va'a. Adapt Phys Activ Q 2020; 37(3): 241-252
32. Delgado R, Tibau X-A. Why Cohen's Kappa should be avoided as performance measure in classification. PLoS One 2019; 14(9): e0222916
33. Hallgren KA. Computing inter-rater reliability for observational data: an overview and tutorial. Tutor Quant Methods Psychol 2012; 8(1): 23-34
34. Budō: The Martial Ways of Japan. Tokyo: Nippon Budokan Foundation; 2009
35. Dictionary of Sport and Exercise Science: [Over 5000 Terms Clearly Defined]. London: A & C Black; 2006

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Article

Behavioural Improvements in Children with Autism Spectrum Disorder after Participation in an Adapted Judo Programme Followed by Deleterious Effects during the COVID-19 Lockdown

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Abstract: The public health lockdown prompted by the novel coronavirus (COVID-19) pandemic, which included school closures that may have potentially serious consequences for people with disabilities or special educational needs, disrupted an ongoing adapted judo training intervention in children with Autism Spectrum Disorder (ASD). The purpose of this study was to compare repetitive behaviours, social interaction, social communication, emotional responses, cognitive style and maladaptive speech scores across four time-points: baseline, after an eight-week control period, after an eight-week judo intervention and after an eight-week lockdown period due to COVID-19. The sample consisted of 11 children diagnosed with ASD according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders—Fifth Edition (DSM-V), with an intelligence quotient (IQ) range between 60 and 70. Significant improvements were shown following the judo intervention period compared to the baseline and control periods. However, the same values significantly declined during the COVID-19 lockdown period resulting in values lower than those recorded at baseline, and following the control period and the judo intervention. The decline in psychosocial and behavioural scores are likely due to the stress caused by the sudden halt in activity and the increase in sedentary practices associated with the lockdown.

Keywords: ASD; Autism; adapted judo programme; exercise intervention; physical activity; COVID-19; lockdown; GARS

1. Introduction

Autism Spectrum Disorder (ASD) is a developmental disorder that involves deficits in social interaction, communication and behaviour. Children with ASD are at risk of physical inactivity due to social and behavioural problems [1]. These individuals tend to spend less time on physical exercise [2] while displaying more deficient motor skills and physical conditioning than their typically developing children [3,4]. In recent years, researchers have attempted to quantify the effects of physical exercise on the motor skills of children with ASD and to develop recommendations for professionals who work with this population [5,6]. The potential for physical activity to enhance the relationship and communication skills in children with ASD has been established, with evidence showing that exercise can lead to improvements in social interactions with classmates, parents, siblings and teachers [7–9].

Despite the clear developmental benefits of physical activity, many children with ASD have a relatively sedentary lifestyle [10]. Short-term participation in physical activity could lead to a decrease in functional difficulties, including behaviours like hyperactivity, aggression and self-harm that are common in children with ASD [1]. In addition, long-term engagement may reduce mortality and morbidity associated with chronic adult diseases such as cardiovascular dysfunction and obesity [1,10]. Unfortunately, individuals with ASD often face obstacles that limit engagement in physical activity levels under normal circumstances. Participating in sports is often further limited because of behavioural problems, motor skill deficits or a lack of trained instructors or peer exercise partners [11].

In response to these challenges, several programmes aimed exclusively at people with ASD have been developed, including a range of physical activities and sports initiatives to enhance social skills and quality of life. The results of these investigations have been positive, with reports of improved social, communication, self-regulation, and motor skill [12–15]. The benefits appear to be more than transient changes, as demonstrated by Zanobini and Solari [16], who found improved relational behaviours and aquatic skills six months after participating in a swimming programme. Therefore, additional information on successful physical activity engagement for children with ASD and promotion of the enjoyment of sports may assist in limiting the potentially harmful effects of a sedentary lifestyle within this population.

The available evidence examining the use of adapted martial arts activities for individuals with ASD shows that participation can be effective, especially when it comes to enhancing motor skills [17,18] and social behaviour. For example, a study of karate participants reported significant improvements in stereotypical behaviour and social interaction [19,20]. While martial arts training may be beneficial due to coupling moderate to high-intensity physical exercise with mental skills or mindfulness practice [21], it may be particularly appealing to those with ASD because of the repetitive structure of the movements involved [22]. Aikido has been found to reduce the symptoms of children with ASD associated with social ability, physical ability and communication behaviours [23]. Recent studies designed to study the effects of participation in judo on children with ASD have yielded initial results that point toward some psychosocial improvements [24]. These programmes also seem to represent an effective way to promote moderate to high-intensity physical activity among this population and curb their tendency toward a sedentary lifestyle [21]. We believe that judo practice, and the overall health benefits it offers like other forms of physical exercise, also provides specific benefits that come from the opportunity to establish physical contact mediated through the grip in the judo uniform with their partners. It has been demonstrated that physical contact, competition and cooperation situations that occur in judo sessions contribute to the well-being and social integration of children in the general population [25,26] and children with intellectual disabilities in particular [27]. These benefits could include discipline, respect, cognitive aspects, autonomy, and not specifically physical fitness, but functional fitness that will improve daily life activities. All this together would facilitate children with ASD being part of society and enjoying being included in it.

The literature shows that the primary objective of most sports programmes aimed at people with ASD is to reduce the prevalence of sedentary behaviour [2]. Inactivity prevention is necessary because the patterns of communication difficulties, anxiety, and lack of social interaction typical of this population tend to be associated with low levels of participation in moderate to high-intensity physical activities and greater amounts of time spent engaging in sedentary behaviours [28]. In this sense, martial arts training can also be helpful to reduce stress and anxiety/depression symptoms in autistic children [29,30]. In particular, the practice of judo has shown positive results in typically developing adolescents [31].

Meanwhile, the extremely unusual situation that struck the world in 2020 due to the novel coronavirus (COVID-19) has caused school closings and confined children to their homes [32]. Consequently, all the adapted sport and physical activity programmes for

children with ASD have been brought to a halt. The suspension of these activities will have potentially serious consequences for people with disabilities or special educational needs, as they are vulnerable to abandonment and lack of stimuli [33]. This unprecedented lockdown situation and the resulting lack of physical activity and excess of sedentary behaviour could have unexpected effects on children with ASD.

When the COVID-19 crisis began, we were in the midst of an adapted judo project with a group of children with ASD, with the backing of the European Union's ERASMUS + Sport programme. The initiative included six different countries and was scheduled to run through the 2020–2021 and 2021–2022 school years. The original project proposal called for measuring the effects of an eight-week adapted judo programme on the children's motor and psychosocial skills. The sudden interruption of the programme because of the COVID-19 health crisis and lockdown meant that we could not complete the second round of motor skill testing. We were, however, able to administer the post-test questionnaires on the psychosocial variables. More importantly, the situation afforded us the opportunity to take the research in an innovative direction by collecting psychosocial data for eight weeks of the lockdown and comparing these data to those collected during the intervention period and baseline values.

Thus, the main objective of this study is to compare the behavioural scores on the six Gilliam Autism Rating Scale (GARS) subscales obtained by children with ASD during three different periods (baseline/control, judo intervention and lockdown). We hypothesise that the participants will show improved behaviour during the adapted judo intervention and that their behaviour ratings will decline during the COVID-19 lockdown period. Due to the relatively short-term duration of the training intervention, social interaction and social communication were expected to exhibit the most pronounced improvements.

2. Materials and Methods

2.1. Participants

We recruited a convenience sample in special education schools that consisted of 11 boys (n = 7) and girls (n = 4) ranging from 9 to 13 years of age with an average age of 10.17 ($\pm$2.45) years, an average height of 153.18 ($\pm$6.48) cm and an average weight of 53.71 ($\pm$6.11) kg. Initially, the study began with 15 participants, 2 of them dropped out for reasons unrelated to the study, and 2 of them did not complete all the sessions. Finally, the data of the 11 participants were used (Figure 1). The children were invited to participate via several associations of families with children with ASD and special education schools from Barcelona (Spain) area. All participants had been diagnosed with ASD according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders—Fifth Edition (DSM-V), and the psychological reports provided by the participants reported an intelligence quotient (IQ) range between 60 and 70 (mean of 66.5 $\pm$ 3.77). Individuals who had been advised against physical activity for medical reasons were excluded, as were those who had previously taken judo classes. The participants were invited to participate in the study voluntarily, and along with their parents, they were informed verbally and in writing as to the programme's characteristics. Parents or legal guardians signed informed consent forms, and the children signed a consent document that explained the objectives and planned activities of the programme. The study was approved by the Research Ethics Committee of Ramon Llull University with reference number CER URL_2019_2020_003. All protocols applied in this research (including managing the participants' personal data) complied with the requirements specified in the Declaration of Helsinki of 1975 and its subsequent revisions. The trial was registered in clinicaltrials.gov (NCT04523805).

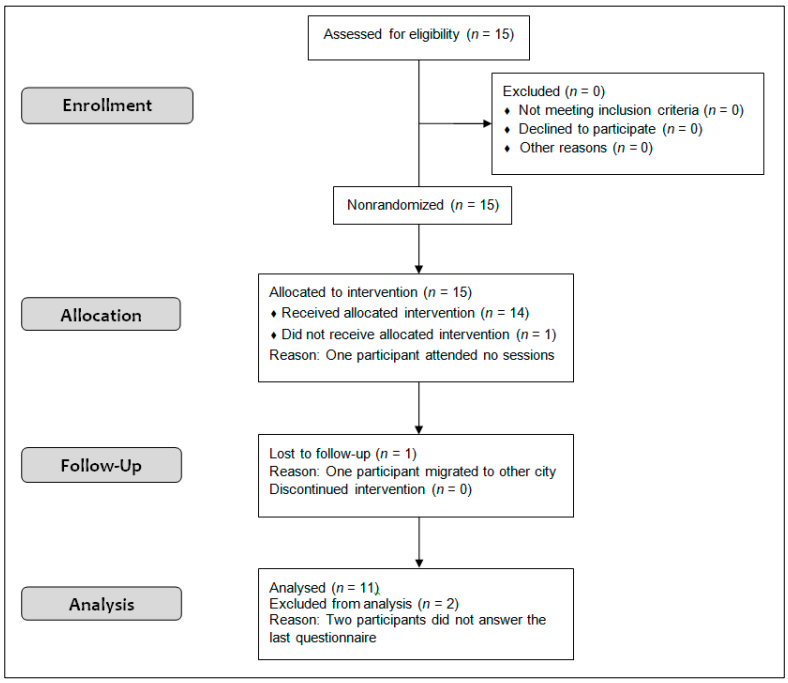

Figure 1. Flow chart of the Transparent Reporting of Evaluations with Non-randomized Designs (TREND) shows the number of participants through each stage of the study.

2.2. Procedure

After the preliminary procedures described above, the research design consisted of a longitudinal study in which data were collected on each participant at four different time points (Figure 2) between 23 November 2019 and 9 May 2020. Baseline data were collected at time point 1 (T1-Baseline), at the start of the programme, and eight weeks later, scores were recorded for time point 2 (T2-Control), which represents a control period. During the control period, part of which included the winter break from classes, the students did not participate in any extracurricular physical activities; thus, their organised physical exercise was limited to their regular physical education classes at school. Between this second measurement and time point 3 (T3-Judo), the eight-week judo intervention was conducted, which consisted of weekly adapted 75-min judo sessions. The final period consisted of eight weeks of the obligatory lockdown imposed by the health authorities in Spain due to the COVID-19 crisis on 14 March 2020, culminating in the final measurement at time point 4 (T4-Lockdown).

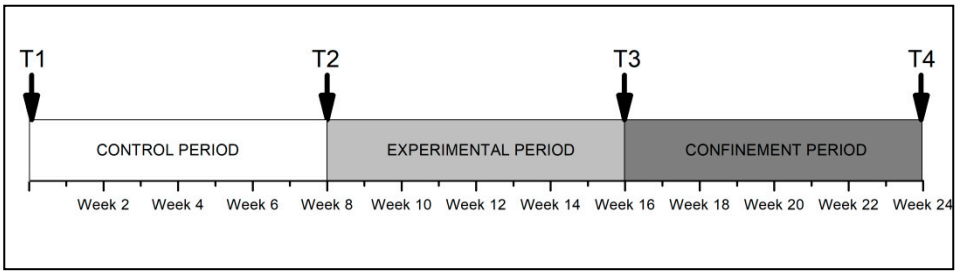

Figure 2. Study timeline. All participants were assessed four times: once as a baseline measurement upon entry to the programme (T1-Baseline), a second time after an eight-week control period (T2-Control), a third time after an eight-week adapted judo intervention (T3-Judo) and a fourth time after an eight-week lockdown period due to COVID-19 (T4-Lockdown).

The choice was made to include the control period at the start of the process because we did not have a control group willing to submit to all the measurements throughout the

project. In the absence of a control group, it was decided to take the second measurement, after which the participants only took part in the compulsory physical education activities at their schools.

The same adapted Judo programme is carried out in six countries of the European Union; nevertheless, only data of one of the countries are included in the present study. The reasons behind that decision are the insufficient data homogeneity in all the countries based on varying lockdown dates, the lack of control period and different intervention times. Therefore, we considered it appropriate to include only the data from one of the countries to ensure rigour and control in the data collection as part of an initial evaluation before examining a larger sample.

2.3. Intervention

The judo sessions were performed in a large and well-ventilated space suitable for judo practice, such that the safety of the participants was maintained. The judo equipment required for this project included a tatami mat with a surface area of 120 m^2, made of high-density foam that helps prevent injuries and ensures that a wide range of activities can be carried out safely. Each participant wore a judogi (a traditional uniform consisting of a cotton jacket and trousers and a belt).

The sessions were 75 min in duration and were held once a week. Two judo teachers with degrees in pedagogy and sports sciences and 7th and 6th-degree black belts, respectively, led each session, and at least four volunteer judo instructors were present to lend support. The sessions were divided into a warm-up, main exercise and cool-down activities. The main exercise content of the sessions included:

- Different types of movements and falling techniques (from walking in all directions to turning around, from stable movements to unstable movements).
- Judo techniques and opposition games (building up body contact with games, teaching simplified movements, basic judo movements).
- Ground control techniques and throws (gradually adding techniques to already known movements, scaffolding basic repetitive movements to assist in understanding those more relevant for judo).
- Repetition of different forms of foundational directional movements (pulling, pushing, holding, lifting).

The instructional methodology applied the principles of gradual progression, featuring practice to consolidate the concepts learned in the initial lessons before moving on to more complex material. Each participant was allowed to progress at their own pace. Learning was based on imitation and guided modelling of techniques.

2.4. Instruments

All participants were assessed at the previously described timepoints using the Gilliam Autism Rating Scale-Third Edition (GARS-3) scale [34]. The GARS-3 is one of the most commonly used instruments to assess changes in the severity of ASD behaviours. It includes 56 items describing the characteristic behaviours of individuals with ASD. The items consisted of six subscales: repetitive behaviours, social interaction, social communication, emotional responses, cognitive style, and maladaptive speech. Parents or caregivers scored each item on a four-point Likert-type scale (0 = never observed; to 3 = frequently observed). A higher score indicates severity of autism-related behaviours, and a lower value represents an improvement. The instrument can be administered in 5–10 min, and it is based on the frequency of occurrence of each item under ordinary circumstances in a six-hour period. The raw score for each subscale was used.

For the first three measurements (T1-Baseline, T2-Control and T3-Judo), parents completed the questionnaire with pen and paper, and they were allowed to ask questions about the interpretation of a given item. For the final measurement (T4-Lockdown), parents and caregivers received a Google Forms hyperlink by email and completed the GARS-

3 online. Parents and caregivers did not report any issue when completing the online questionnaire, likely because they were already familiar with the instrument.

2.5. Statistical Analysis

All descriptive data from the dependent variables are presented as mean ± standard deviation (SD). The normal distribution of each variable was checked with a Shapiro–Wilk test. The analysis of the outputs from each GARS-3 subscale at the four-time points (T1-Baseline, T2-Control, T3-Judo and T4-Lockdown) were carried out using one-way repeated measures multivariate ANOVA with follow-up univariate analyses with Bonferroni post hoc correction for multiple comparisons. All statistical analyses were conducted using the Statistical Package for Social Science version 24.0 software (SPSS, Inc., Chicago, IL, USA). A significance level of $p < 0.05$ was used for all tests.

3. Results

One-way repeated measures multivariate ANOVA of the mean GARS-3 score across all subscales showed a significant main effect within subjects ($F_{18,81} = 4.75$, $p < 0.05$; $\eta_p^2 = 0.51$). Univariate contrast showed a significant effect for time on four of the six subscales: repetitive behaviours, social interaction, social communication and emotional responses. In all cases, the sphericity assumption was violated and the number of degrees of freedom was adjusted using the Huynh–Feldt method, repetitive behaviours ($F_{1.36,15.09} = 15.48$, $p < 0.05$; $\eta_p^2 = 0.61$); social interaction ($F_{1.12,11.62} = 25.55$, $p < 0.05$; $\eta_p^2 = 0.71$); social communication ($F_{1.27,13.82} = 18.21$, $p < 0.05$; $\eta_p^2 = 0.64$); emotional responses ($F_{1.68,19.89} = 76.95$, $p < 0.05$; $\eta_p^2 = 0.88$).

Pairwise comparisons (Figure 3) indicated a significant improvement ($p < 0.05$) following the 8-week adapted judo training intervention at T3-Judo in repetitive behaviours, social interaction, social communication and emotional responses subscales compared with each of the other time points (T1-Baseline, T2-Control and T4-Lockdown). On the other hand, the cognitive style and maladaptive speech subscales did not show significant differences in any of the measurements. It should be noted that a low score indicates a decrease in the severity of the characteristics of children with ASD. Furthermore, a deterioration in the same subscales was observed following the 8-week COVID-19 lockdown period at T4-Lockdown compared to the other time points (T1-Baseline, T2-Control and T3-Judo). No significant differences in any of the subscales were observed during the control period between T1-Baseline and T2-Control.

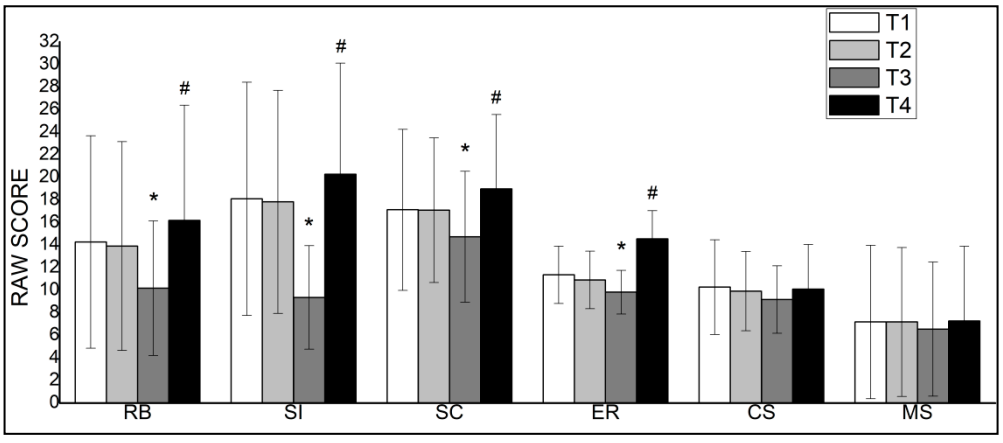

Figure 3. Gilliam Autism Rating Scale-Third Edition (GARS-3) subscales for repetitive behaviours (RB), social interaction (SI), social communication (SC), emotional responses (ER), cognitive style (CS), and maladaptive speech (MS) at baseline (T1-Baseline), after the 8-week control period (T2-Control), after the 8-week judo training intervention (T3-Judo), and after the 8-week COVID-19 lockdown period (T4-Lockdown). * significantly different ($p < 0.05$) from T1-Baseline, T2-Control, and T4-Lockdown. # significantly different ($p < 0.05$) from T1-Baseline, T2-Control, and T3-Judo.

4. Discussion

This study confirms the positive effects of 8-week adapted judo training in repetitive behaviours, social interaction, social communication and emotional responses subscales in children with ASD. Furthermore, our results provide evidence of the indirect, potentially harmful effects on children with ASD during the lockdown imposed by the health authorities to stop the spread of COVID-19. The interpretation and limitations of the present study must be considered with respect to the exceptionality of the situation caused by the COVID-19 pandemic which altered the original intervention. This situation has caused an interruption in their daily routines leading to the increased time spent engaging in sedentary activities such as watching television and using electronic devices [35]. Under these circumstances, children with ASD risk losing the benefits they may have previously attained from an active lifestyle, which is demonstrated by the GARS-3 subscale scores measured in excess of baseline and control values prior to the improvements conferred by the adapted judo programme.

The overall results show that the participants recorded significantly better scores ($p < 0.05$) on the subscales repetitive behaviours, social interaction, social communication and emotional responses during the adapted judo intervention period than they did during the control period or during the lockdown. The first of the subscales, repetitive behaviours, measures the restrictive/repetitive behaviours displayed by children with ASD. It corresponds to the subscale on stereotyped behaviours in the previous version of the testing instrument (GARS-2). The most common of these behaviours include a rocking motion of the hands, nodding, shaking arms, sudden running, rocking the body forward and backward, repeated manipulation of objects and finger movements [36]. Our results agree with those obtained by the Ferreira et al. [37] meta-analysis that reported children with ASD showed 1.1 fewer instances of stereotyped behaviours after an intervention with physical exercise. This clear indication of the effectiveness of physical activity for children with ASD has also been demonstrated following a variety of interventions, including an eight-week sports programme based on exercise with a ball [13], a ten-week horseback riding programme [38] and a programme linking physical exercise to video games [39].

The results of this study also, in essence, confirm prior research examining the use of combat sports or martial arts to improve certain executive and psychosocial behaviours that also influence the quality of life of children with ASD. For example, an intervention with adapted mixed martial arts [40] found improvements in executive functioning and reduced repetitive behaviours. These researchers attribute the improvements to the ability of these sporting activities to be adapted to the individual needs, preferences, and training status of children with ASD. Bahrami et al. [20] also achieved positive results in terms of reduced stereotypical behaviours following a karate kata intervention with highly structured activities calling for participants to follow a classmate or instructor's movements and imagine scenarios with opponents. The success of our adapted judo programme could be partially due to its grounding in traditional martial arts practices, which, in addition to developing physical skills, aim to hone participants' self-discipline and enhance their behavioural, emotional and cognitive control [21]. These psychosociological benefits align with the recommendations of the most successful martial arts interventions for children with ASD [20,40].

The social interaction, social communication and emotional responses subscales, which are closely connected to social ability, also displayed significant improvements following the judo intervention over the scores for the control period. These results support and confirm previous findings showing that participation in sport can improve the social abilities of children with ASD and help improve engagement in social interactions [15,16]. Sports programmes [13,14] are ideal for fostering positive social ability since the very act of participation and need for teamwork involved afford children innumerable opportunities to interact with one another. The current findings coincide with Movahedi et al. [19], which showed socio-emotional improvements after a karate intervention that requires participants to engage with their surroundings and with one another. In our research,

touch or contact is our most social sense since it involves exploring the environment and engaging in successful interactions, forming interpersonal attachments. In that regard, judo practice involves physical contact situations during standing and groundwork, and contact situations have a potential role in developing bodily self-awareness defined as the ability to sense and recognise our body as our own [41]. The information that arises from inside the body gives information about its movement and location in the space (e.g., proprioceptive, vestibular and kinaesthetic input) and the perception of its physiological condition [41]. Thus, our adapted judo programme introduced a progressive increase in oppositional situations where physical contact is promoted between peers in simple to increasingly complex situations, thus eliciting progressive training of perception and decision-making skills. Contact experienced by the participants during the adapted judo programme may have stimulated positive adaptations in self-awareness in addition to the enhancement obtained in behavioural, social and emotional skills. Future works are warranted to investigate the effects of judo practice on self-awareness in children with ASD.

Cognitive style and maladaptive speech did not present differences during the lockdown period or the adapted judo programme. Nevertheless, some physical activity interventions have shown improvements in cognitive functioning [39,42], likely because the control of bodily movement developed in the context of sport involves decision making, anticipation and the measuring of speed and trajectories, all of which are associated with cognitive skills [43]. Nonetheless, cognitive improvements and decreases in inappropriate language are less positively affected by interventions with minimal physical activity compared to social abilities [44]. For example, Pan et al. [43] found significant improvements on only three of the six indices of the Wisconsin Card Sorting Test, while Anderson-Hanley et al. [39] found significant progress on the Digit Span Backward Task, but not the Color Trails or Stroop Tests. These findings suggest that the two subscales in question might not be sensitive to participation in an adapted judo programme while potentially being more connected to other symptoms within the broad spectrum of autism.

The results following the COVID-19 lockdown showed a significant, generalised decline in the same behavioural measures (repetitive behaviours, social interaction, social communication and emotional responses) that were improved with the adapted judo programme in children with ASD. The quarantine likely resulted in additional stress among parents and damage to the mental health of children with ASD, leading to a greater number of episodes of aggression and maladjusted behaviour [45]. According to Narzisi [46], during the COVID-19 lockdown period, children with ASD may have an increased tendency toward stereotyped behaviour because of the new stress caused by changes in the daily routine. Meanwhile, it is also possible that the deterioration in behaviours was due to the lockdown and the halt of the adapted judo programme, as in this study, it is impossible to separate these two factors. The fact that the baseline (T1) and control scores (T2) were lower than the results after eight weeks of the lockdown agrees with other recent studies of children with ASD [47] that reported worsened sleep problems and autism symptoms during the lockdown. These factors may be compounded by the preference of individuals with ASD for sedentary activities, especially those involving screens [2], which can increase their risk of obesity and cardiovascular disease [10].

In order to counteract these harmful outcomes, it would be beneficial for children with ASD to continue engaging in physical activity interventions at home during quarantine orders to maintain overall health and immune function while minimising sedentary screen time [45]. Narzisi [46] recommends that parents and children share activities and play semi-structured games together or do exercise routines using online videos; however, there is an inherent need for familial support for these efforts to be successful. Furthermore, there is a wealth of resources and articles that offer examples of physical activities to do with children with ASD and strategies to encourage them to be more active [35]. As part of our project, we have created online judo materials to offer the study participants the opportunity to receive judo instruction remotely.

The limitations of this study stem from the small sample size. However, it is worth emphasising the difficulties involved in taking longitudinal measurements of a group of children with ASD due to their high drop-out rate and their tendency to display a low degree of continuity in physical exercise. Because of the difficulties discussed above, we could not recruit a control group, representing another limitation of the study. However, we established a control period, during which the participants did not do any extracurricular sports that also encompassed their winter break from classes. Finally, the fact that the parents or guardians completed the questionnaires could have affected the results. While they were certainly in the best position to follow the participants' progress, they may also have been influenced by their expectations of the adapted judo programme or the stress they experienced during the lockdown. Therefore, these expectations force us to consider these data as preliminary results that require a more extended period of intervention to allow for broader interpretation.

5. Conclusions

The eight-week adapted judo training intervention positively affected repetitive behaviours, social interaction, social communication, and emotional responses subscales in children with ASD. On the other hand, the cognitive style and maladaptive speech subscales did not show significant differences in any of the measurements. The COVID-19 lockdown period resulted in an apparent deterioration of repetitive behaviour, social interaction, social communication and emotional response returning to baseline values in children with ASD. The cognitive style and maladaptive speech subscales did not display any changes over any of the periods. Further studies could attempt to replicate or expand these findings either in-person or remotely and incorporate factors that influence cognition or language into the judo programme. The long-term effects of these interventions also need to be explored, while additional aspects of behaviour, including issues connected to motor skills, should be examined.

Author Contributions: J.M. conceptualised the study, analysed the data, and wrote the manuscript. D.H.F. assisted with conceptualising the study, and writing/editing the manuscript. V.G. assisted with data collection, and editing the manuscript. E.P. assisted with data collection, and writing/editing the manuscript. C.C. assisted with data collection, and writing/editing the manuscript. J.O.M.-F. assisted with interpretation of the results and writing/editing the manuscript. A.M.G. assisted with interpretation of the results and editing the manuscript. E.C. assisted with data collection, and writing/editing the manuscript. M.G.-B. conceptualised the study, analysed the data, and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was approved by the Research Ethics Committee of Ramon Llull University, with reference number CER URL_2019_2020_003. All protocols applied in this research (including the management of the personal data of the participants) complied with the requirements specified in the Declaration of Helsinki of 1975 and its subsequent revisions.

Informed Consent Statement: Parents or legal guardians signed written informed consent forms, and the children signed a consent document that explained the objectives and planned activities of the programme.

Data Availability Statement: All data files are available from the FIGSHARE database: https://figshare.com/s/2943e0ef5369efcbf48f (accessed date on 30 June 2020).

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References

1. Bricout, V.-A.; Pace, M.; Dumortier, L.; Baillieul, F.; Favre-Juvin, A.; Guinot, M. Reduced Cardiorespiratory Capacity in Children with Autism Spectrum Disorders. *J. Clin. Med.* **2018**, *7*, 361. [CrossRef] [PubMed]
2. Healy, S.; Haegele, J.A.; Grenier, M.; Garcia, J.M. Physical activity, screen-time behavior, and obesity among 13-year olds in Ireland with and without autism spectrum disorder. *J. Autism Dev. Disord.* **2017**, *47*, 49–57. [CrossRef] [PubMed]
3. Pan, C.-Y. Motor proficiency and physical fitness in adolescent males with and without autism spectrum disorders. *Autism* **2014**, *18*, 156–165. [CrossRef] [PubMed]
4. Tyler, K.; MacDonald, M.; Menear, K. Physical activity and physical fitness of school-aged children and youth with autism spectrum disorders. *Autism Res. Treat.* **2014**, *2014*, 312163. [CrossRef]
5. Sam, K.-L.; Chow, B.-C.; Tong, K.-K. Effectiveness of exercise-based interventions for children with autism: A systematic review and meta-analysis. *Int. J. Learn. Teach.* **2015**, *1*, 98–103. [CrossRef]
6. Sowa, M.; Meulenbroek, R. Effects of physical exercise on autism spectrum disorders: A meta-analysis. *Res. Autism Spectr. Disord.* **2012**, *6*, 46–57. [CrossRef]
7. Howells, K.; Sivaratnam, C.; May, T.; Lindor, E.; McGillivray, J.; Rinehart, N. Efficacy of Group-Based Organised Physical Activity Participation for Social Outcomes in Children with Autism Spectrum Disorder: A Systematic Review and Meta-analysis. *J. Autism Dev. Disord.* **2019**, *49*, 3290–3308. [CrossRef] [PubMed]
8. Healy, S.; Nacario, A.; Braithwaite, R.E.; Hopper, C. The effect of physical activity interventions on youth with autism spectrum disorder: A meta-analysis. *Autism Res.* **2018**, *11*, 818–833. [CrossRef]
9. Bremer, E.; Crozier, M.; Lloyd, M. A systematic review of the behavioural outcomes following exercise interventions for children and youth with autism spectrum disorder. *Autism* **2016**, *20*, 899–915. [CrossRef]
10. McCoy, S.M.; Jakicic, J.M.; Gibbs, B.B. Comparison of obesity, physical activity, and sedentary behaviors between adolescents with autism spectrum disorders and without. *J. Autism Dev. Disord.* **2016**, *46*, 2317–2326. [CrossRef]
11. Stanish, H.; Curtin, C.; Must, A.; Phillips, S.; Maslin, M.; Bandini, L. Enjoyment, barriers, and beliefs about physical activity in adolescents with and without autism spectrum disorder. *Adapt. Phys. Act. Q.* **2015**, *32*, 302–317. [CrossRef] [PubMed]
12. Duffy, L.; Baluch, B.; Welland, S.; Raman, E. Effects of physical activity on debilitating behaviours in 13-to 20-year-old males with severe autism spectrum disorder. *J. Exerc. Rehabil.* **2017**, *13*, 340. [CrossRef]
13. Najafabadi, M.G.; Sheikh, M.; Hemayattalab, R.; Memari, A.-H.; Aderyani, M.R.; Hafizi, S. The effect of SPARK on social and motor skills of children with autism. *Pediatr. Neonatol.* **2018**, *59*, 481–487. [CrossRef]
14. Shanok, N.A.; Sotelo, M.; Hong, J. Brief Report: The Utility of a Golf Training Program for Individuals with Autism Spectrum Disorder. *J. Autism Dev. Disord.* **2019**, *49*, 4691–4697. [CrossRef] [PubMed]
15. Zhao, M.; Chen, S. The effects of structured physical activity program on social interaction and communication for children with autism. *Biomed Res. Int.* **2018**, *2018*, 1825046. [CrossRef]
16. Zanobini, M.; Solari, S. Effectiveness of the Program "Acqua Mediatrice di Comunicazione"(Water as a Mediator of Communication) on Social Skills, Autistic Behaviors and Aquatic Skills in ASD Children. *J. Autism Dev. Disord.* **2019**, *49*, 4134–4146. [CrossRef] [PubMed]
17. Kim, Y.; Todd, T.; Fujii, T.; Lim, J.-C.; Vrongistinos, K.; Jung, T. Effects of Taekwondo intervention on balance in children with autism spectrum disorder. *J. Exerc. Rehabil.* **2016**, *12*, 314–319. [CrossRef]
18. Sarabzadeh, M.; Azari, B.B.; Helalizadeh, M. The effect of six weeks of Tai Chi Chuan training on the motor skills of children with Autism Spectrum Disorder. *J. Bodyw. Mov. Ther.* **2019**, *23*, 284–290. [CrossRef] [PubMed]
19. Movahedi, A.; Bahrami, F.; Marandi, S.M.; Abedi, A. Improvement in social dysfunction of children with autism spectrum disorder following long term Kata techniques training. *Res. Autism Spectr. Disord.* **2013**, *7*, 1054–1061. [CrossRef]
20. Bahrami, F.; Movahedi, A.; Marandi, S.M.; Abedi, A. Kata techniques training consistently decreases stereotypy in children with autism spectrum disorder. *Res. Dev. Disabil.* **2012**, *33*, 1183–1193. [CrossRef]
21. Garcia, J.M.; Leahy, N.; Rivera, P.; Renziehausen, J.; Samuels, J.; Fukuda, D.H.; Stout, J.R. Brief Report: Preliminary Efficacy of a Judo Program to Promote Participation in Physical Activity in Youth with Autism Spectrum Disorder. *J. Autism Dev. Disord.* **2019**, *50*, 1418–1424. [CrossRef]
22. Bell, A.; Allen, M. Using Martial Arts to Address Social and Behavioral Functioning in Children and Adolescents With Autism Spectrum Disorder. *Ther. Recreat. J.* **2016**, *50*, 176–181. [CrossRef]
23. Polak, E.; Sikora, J.; Rachwał, M. An aikido-based intervention supporting the therapy of a child with autism spectrum disorders–a case study. *Ido Mov. Cult. J. Martial Arts Anthropol.* **2019**, *19*, 67–76.
24. Rivera, P.; Renziehausen, J.; Garcia, J.M. Effects of an 8-Week Judo Program on Behaviors in Children with Autism Spectrum Disorder: A Mixed-Methods Approach. *Child Psychiatry Hum. Dev.* **2020**, *51*, 734–741. [CrossRef] [PubMed]
25. Geertz, W.; Dechow, A.-S.; Pohl, E.; Zyriax, B.-C.; Ganschow, R.; Schulz, K.-H. Physical and psychological well-being in overweight children participating in a long-term intervention based on judo practice. *Adv. Phys. Educ.* **2017**, *7*, 85. [CrossRef]

26. Carratalá, V.; Marco-Ahulló, A.; Carratalá, I.; Carratalá, H.; Bermejo, J.-L. Judo as a tool for social integration in adolescents at risk of social exclusion: A pilot study. *J. Hum. Sport Exerc.* **2019**, *15*, 202–216. [CrossRef]
27. Oblak, V.P.; Karpljuk, D.; Vodičar, J.; Šimenko, J. Inclusion of people with intellectual disabilities in judo: A systematic review of literature. *Environment* **2020**, *5*, 8.
28. Srinivasan, S.M.; Pescatello, L.S.; Bhat, A.N. Current perspectives on physical activity and exercise recommendations for children and adolescents with autism spectrum disorders. *Phys. Ther.* **2014**, *94*, 875–889. [CrossRef] [PubMed]
29. Naves-Bittencourt, W.; Mendonça-de-Sousa, A.; Stults-Kolehmainen, M.; Fontes, E.; Córdova, C.; Demarzo, M.; Boullosa, D. Martial arts: Mindful exercise to combat stress. *Eur. J. Hum. Mov.* **2015**, *34*, 34–51.
30. Baron, L.J.; Faubert, C. The role of Tai Chi Chuan in reducing state anxiety and enhancing mood of children with special needs. *J. Bodyw. Mov. Ther.* **2005**, *9*, 120–133. [CrossRef]
31. Yukimoto, Y.; Akira, K. Psychological changes in anxiety, enjoyment, and value of learning in junior high school students learning judo. *J. Phys. Educ. Sport* **2021**, *21*, 1676–1681. [CrossRef]
32. Lee, J. Mental health effects of school closures during COVID-19. *Lancet. Child Adolesc. Health* **2020**, *4*, 421. [CrossRef]
33. Wang, G.; Zhang, Y.; Zhao, J.; Zhang, J.; Jiang, F. Mitigate the effects of home confinement on children during the COVID-19 outbreak. *Lancet* **2020**, *395*, 945–947. [CrossRef]
34. Gilliam, J.E. *GARS-3: Gilliam Autism Rating Scale*, 3rd ed.; Pro-Ed Publishers: Austin, TX, USA, 2014.
35. Chen, P.; Mao, L.; Nassis, G.P.; Harmer, P.; Ainsworth, B.E.; Li, F. Coronavirus disease (COVID-19): The need to maintain regular physical activity while taking precautions. *J. Sport Heal. Sci.* **2020**, *9*, 103–104. [CrossRef]
36. Hattier, M.A.; Matson, J.L.; Macmillan, K.; Williams, L. Stereotyped behaviours in children with autism spectrum disorders and atypical development as measured by the BPI-01. *Dev. Neurorehabil.* **2013**, *16*, 291–300. [CrossRef] [PubMed]
37. Ferreira, J.P.; Ghiarone, T.; Cabral Júnior, C.R.; Furtado, G.E.; Moreira Carvalho, H.; Machado-Rodrigues, A.M.; Toscano, A.; Vasconcelos, C. Effects of Physical Exercise on the Stereotyped Behavior of Children with Autism Spectrum Disorders. *Medicina* **2019**, *55*, 685. [CrossRef] [PubMed]
38. Gabriels, R.L.; Agnew, J.A.; Holt, K.D.; Shoffner, A.; Zhaoxing, P.; Ruzzano, S.; Clayton, G.H.; Mesibov, G. Pilot study measuring the effects of therapeutic horseback riding on school-age children and adolescents with autism spectrum disorders. *Res. Autism Spectr. Disord.* **2012**, *6*, 578–588. [CrossRef]
39. Anderson-Hanley, C.; Tureck, K.; Schneiderman, R.L. Autism and exergaming: Effects on repetitive behaviors and cognition. *Psychol. Res. Behav. Manag.* **2011**, *4*, 129–137. [CrossRef] [PubMed]
40. Phung, J.N.; Goldberg, W.A. Promoting Executive Functioning in Children with Autism Spectrum Disorder Through Mixed Martial Arts Training. *J. Autism Dev. Disord.* **2019**, *49*, 3669–3684. [CrossRef]
41. Critchley, H.D.; Wiens, S.; Rotshtein, P.; Öhman, A.; Dolan, R.J. Neural systems supporting interoceptive awareness. *Nat. Neurosci.* **2004**, *7*, 189–195. [CrossRef]
42. Sorensen, C.; Zarrett, N. Benefits of physical activity for adolescents with autism spectrum disorders: A comprehensive review. *Rev. J. Autism Dev. Disord.* **2014**, *1*, 344–353. [CrossRef]
43. Pan, C.-Y.; Chu, C.-H.; Tsai, C.-L.; Sung, M.-C.; Huang, C.-Y.; Ma, W.-Y. The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. *Autism* **2017**, *21*, 190–202. [CrossRef] [PubMed]
44. Gabriels, R.L.; Pan, Z.; Dechant, B.; Agnew, J.A.; Brim, N.; Mesibov, G. Randomized controlled trial of therapeutic horseback riding in children and adolescents with autism spectrum disorder. *J. Am. Acad. Child Adolesc. Psychiatry* **2015**, *54*, 541–549. [CrossRef]
45. Yarımkaya, E.; Esentürk, O.K. Promoting physical activity for children with autism spectrum disorders during Coronavirus outbreak: Benefits, strategies, and examples. *Int. J. Dev. Disabil.* **2020**, 1–6. [CrossRef]
46. Narzisi, A. Handle the autism spectrum condition during Coronavirus (COVID-19) stay at home period: Ten tips for helping parents and caregivers of young children. *Brain Sci.* **2020**, *10*, 207. [CrossRef]
47. Türkoğlu, S.; Uçar, H.N.; Çetin, F.H.; Güler, H.A.; Tezcan, M.E. The relationship between chronotype, sleep, and autism symptom severity in children with ASD in COVID-19 home confinement period. *Chronobiol. Int.* **2020**, *37*, 1207–1213. [CrossRef]

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Effects of a Long-Term Adapted Judo Program on the Health-Related Physical Fitness of Children with ASD

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Abstract: Physical fitness is one of the most important physical and mental health aspects for children with Autism Spectrum Disorder (ASD). This study aimed to test the effects of a long-term adapted judo program on the health-related physical fitness of children with ASD. The participants were recruited from various associations of families and schools for children with special needs. Twenty-one children were assigned to an experimental group and nineteen to a control group. The experimental group participated in a six-month adapted judo program consisting of 90 min of practice each week. Health-related physical fitness was measured using the indicators obtained from the ALPHA-fitness battery, the estimated VO_2max and the waist/height ratio$^{0.5}$. Changes within and between groups were analyzed using linear mixed models for repeated measures designs and test-retest reliability of tests requiring a maximum score using the Intraclass Correlation Coefficient (ICC). A judo program tailored for children with ASD can improve the cardio-metabolic health and cardiorespiratory fitness of its participants. The problems involved with administering physical aptitude tests that involve maximum effort or performance in children with ASD cast serious doubts on the reproducibility of their results.

Keywords: combat sports; autism; intellectual disabilities; adapted sports; non-exercise equation; waist circumference

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1. Introduction

Physical activity and exercise can help children and adolescents achieve a suitable degree of physical fitness. Maintaining a certain level of physical fitness is one of the most important factors for children and adolescents' physical and mental health [1]. The World Health Organization guidelines recommend an average of 60 min/day of moderate-to-vigorous intensity aerobic physical activity and regular muscle-strengthening activity across the week for health benefits in children and adolescents [2,3]. This can be done in various settings, including hobbies, recreation and extracurricular youth sports [4].

Autism spectrum disorder (ASD) is a neurological disorder with an unknown cause that manifests itself in difficulties and deficits associated with communication and social interaction and repetitive and stereotyped behaviors [5]. Children with ASD have been shown to have a lower fitness level than children with typical development [6]. The causal relationship between this difference and ASD is unclear; however, it has been reported that challenges when accessing physical activity programs, bullying, lack of awareness of ASD among service providers or instructors, few adapted program options, or the prioritization of therapeutic interventions limited participation [7,8]. The motivation to practice physical activity regularly in children with ASD is affected by complex physical, cultural and

environmental elements [9–11]. Subsequently, it has been observed that children with ASD tend to be less active, have more motor deficits and, ultimately, live a more sedentary lifestyle [11]. These factors can lead to many chronic diseases, such as obesity, diabetes and cardiovascular diseases [12].

Furthermore, low levels of physical fitness can also reduce social integration [13]. It has been shown that children with ASD show less interest in play and spontaneous games during leisure time activities than their peers without ASD [14], making it difficult to make friends and, therefore, favoring social isolation. Extracurricular sports activities offer an excellent opportunity to increase children's daily PA, stimulate social interactions and appear to be very helpful in preventing illness and improving fundamental motor skills and development in children with ASD [14]. Indeed, structured leisure time activities have positively affected children and adolescents' mental and physical health [15].

The physical and mental health benefits of physical activity for individuals with ASD have been extensively documented in the scientific literature in [9–11,13,16,17]. Some systematic reviews have linked PA to social and communication improvements [18,19], as well as to improved motor skills [20,21]. Other studies have shown how PA and/or exercise programs can improve physical health [22,23].

Martial arts and combat sports involve activities of moderate to vigorous intensity and feature additional cognitive and emotional components such as concentration and self-control [24]. These types of activities are attractive to young people with ASD because of the repetitive structure of the exercises involved [25]. Research supports the effectiveness of these sports not only in improving motor skills [26,27] but in addressing social behavior. For example, the training of karate katas has been found to significantly improve stereotypical behaviors and social interaction [28,29].

The systematic review by Pečnikar et al. [30] highlights the improvements in health parameters and social skills of people with intellectual disabilities when they participate in adapted judo programs. Judo has led to positive results in short-term programs, including improvements in repetitive behaviors, interaction and social communication, and emotional response [16]. Accordingly, a recent study reported [31] a reduction in aggressive behavior in children with ASD who participated in an adapted judo program after an eight-week intervention [31]. Other research demonstrates the viability and effectiveness of this type of program, which can produce a great deal of acceptance and high rates of enjoyment, with participants often expressing a strong desire to continue to take part in the sport after the program is over [32]. It has been reported that adherence to adapted judo programs is associated with an increase in the volume of moderate to vigorous physical activity [24], a fundamental condition for improving the physical fitness of children and adolescents.

Researchers seeking to measure the physical fitness of individuals with ASD face considerable limitations. These issues include communication difficulties, sensory deficits, poor limb function, delayed growth and motor development, defiant behavior and a lack of understanding or motivation to make the required level of effort or to strive for the best possible performance. All of these factors can influence the reliability of a test [33]. In [34,35], the former tests are more cost-efficient and can be carried out in a familiar environment that favors better performance by the participants, even though the latter are usually more precise. A major obstacle researchers face when measuring physical fitness in individuals with ASD is that there is no evidence that certain tests are feasible or reliable with some population subgroups, such as younger children and those with moderate to severe levels of intellectual disability [33].

Therefore, assessing the health-related physical fitness in children with ASD is a challenge. To the best of our knowledge, there are no validated physical fitness batteries of tests exclusively for children with ASD. Generally, the physical fitness in children with ASD has been measured using adaptations of tests for the general population or via existing batteries of tests such as EUROFIT [36,37]. Other batteries, such as the ALPHA health-related fitness test battery [38], have been validated for the population with Down

Syndrome [39] and also have adaptations for preschoolers [40]. The use of such tests is a potential methodology in studies of the field of children with ASD.

Anthropometric measurements have been characterized as a good resource for monitoring cardio-metabolic health in this population because of their ease of administration and the consistency of the measurements they yield. Specifically, BMI has historically been used despite its limitations [41]; however, when measuring on the individual level, there are anthropometric alternatives much more valid than BMI. These alternative measurements are based on the waist-to-height ratio (WHTR) [42] or the allometric index (the waist circumference divided by half the height) (WHT.5R = WC/height0.5). The latter is a measurement of waist circumference independent of height [43]. Meanwhile, the variable of maximal oxygen consumption (VO_2max) is a robust and well-established indicator of cardiovascular health [44] and has proven effective at predicting premature mortality, regardless of its cause [45]. However, it is challenging to perform laboratory or field tests that measure or estimate VO_2max following maximal effort exercise in children with ASD [33]. In situations like this, when the measurement or estimation of VO2max through an exercise protocol is not possible, researchers have suggested the use of "non-exercise estimation models" that make calculations using factors such as age, gender, self-reported level of physical activity, body composition and other parameters [46,47], all variables that can be easily recorded in children with ASD. These models have been validated against laboratory measurements of VO_2max and have reported estimation errors from 3.11 to 5.70 mL/kg/min and goodness of fit from r = 0.50 to r = 0.86 [45].

The wide-ranging evidence of the benefits of physical activity and exercise on the health of children with ASD, and the previously demonstrated efficacy of adapted judo programs in this type of population, led to the adoption of the main objective of this study, which is to assess the effects of a long-term adapted judo program on the health-related physical fitness of children with ASD. The secondary objective was to verify the feasibility and reliability of the indicators used to measure physical fitness in this population.

2. Materials and Methods

2.1. Participants

The GPOWER v3.1 software program (Bonn FRG, University of Bonn, Department of Psychology, Düsseldorf, Germany) was used to calculate the a priori sample size necessary to obtain a Power (1-ß) > 0.9, a large effect size = 0.6 and a type I error = 0.05, two groups and two measurements, with the result being a required total sample of 32 subjects. Based on previous experiences in judo programs with children and adolescents with ASD, we estimated a dropout rate of 20% of the participants during the intervention. Therefore, we recruited forty children for the current study.

The participants' mean age was 11.07 (±1.73) years, height 145.9 (±15.81) cm and weight 47.71 (±16.71) kg. All of them were recruited from various associations of families of children with ASD and schools for children with special needs. All participants had been diagnosed with ASD based on the Diagnostic and Statistical Manual of Mental Disorders—Fifth Edition (DSM-5) criteria. The psychological reports provided by the participants indicated intelligence quotients (IQ) ranging from 60 to 70 (mean of 65.4 ± 3.55). Individuals who had been medically advised against physical exercise, previously participated in judo classes or simultaneously participated in extracurricular sports activities were excluded. All subjects were invited to participate in the study voluntarily, and both the participants and their families were informed verbally and in writing about the characteristics of the program. Subsequently, the parents or legal guardians signed the informed consent document, and the children signed an informed consent form in which the objectives and plan of the program were explained. All the protocols applied in this research, including managing the participants' personal data, comply with the requirements specified in the Declaration of Helsinki of 1975 and its subsequent revisions. This study was approved by the Research Ethics Committee of the Ramon Llull University under document number CER URL_2019_2020_003, and the trial was registered at Clinicaltrials.gov (NCT04523805).

2.2. Procedure

This research used a prospective design. The convenience sample was divided into two groups based on their availability and commitment to participate in an adapted judo program over a school year. The experimental group (n = 21: age = 11.1 years ± 1.9; height = 147.0 ± 15.7; weight = 47.7 kg ± 12.5) participated in the adapted judo program for six months, and the control group (n = 19: age = 11.0 year ± 1.5; height = 144.5 cm ± 15.9; weight = 47.6 kg ± 10.2) did not participate in any extracurricular sports activities during this period. Each participant's weight and height were measured using a digital balance (Seca 707, Hamburg, Germany) and a wall-mounted stadiometer (Seca 220, Hamburg, Germany) following standard procedures (stand with heels, buttocks and upper back against stadiometer), with each participant being assessed twice, once at the beginning of the program and again at the end. Body mass and height were used to calculate the body mass index, according to Quetelet (kg/m^2). All measurements were done under stable conditions and in the same room where the judo sessions were held in Barcelona (Spain) during January 2022 and June 2022.

In order to assess the physical condition of the participants at the two different times of measurement, the ALPHA-fitness battery was administered. This battery of tests evaluates the main components of health-related physical conditioning, including cardiorespiratory fitness, musculoskeletal fitness, body composition and motor fitness. The battery of tests has been shown to have a high degree of versatility in its application to special populations [39]. The reliability of the results of physical fitness tests among the population of children with ASD is subject to a high degree of uncertainty, especially when the sample of participants has a wide range of IQs that includes both midrange and low scores [33]. Therefore, additional steps were taken to ensure the reliability of the tests that involve motivation or require maximum effort. In order to confirm the consistency of the responses, intra-session repetitions of the muscle strength tests and the cardiorespiratory fitness test were carried out 48 h apart. In addition, VO_2max was estimated through a non-exercise equation (NEXE) [46] that uses age, basal heart rate, waist circumference, heart rate and time and intensity of weekly physical activity to estimate cardiovascular capacity. Differences in the factors used to calculate the NEXE have been shown to explain a substantial proportion of the variance in maximal oxygen consumption values among populations of different ages [48–50].

2.3. Intervention

The experimental group participated in an adapted judo program over six months. The judo sessions were held in an ample, well-ventilated space suitable for athletic activity in general and judo in particular, so the safety of the participants was guaranteed. The judo equipment required for this project included a tatami mat with a surface area of 120 m^2, made out of high-density covered foam that helps prevent injuries and ensures that a wide range of activities can be carried out safely. Each participant was outfitted with a judogi (the traditional uniform consisting of a cotton jacket, trousers and a belt).

The 90-min sessions were held once a week. Two judo teachers with 7th and 6th DAN levels led the sessions. One has a degree in Pedagogy, and the other in Sports Science. Furthermore, at least four volunteer judo instructors were available at each session to support. The sessions were divided into three parts following the physiological principles of exercise: warm-up, main exercise and cool-down. The main content of the sessions is included in Table 1.

The instructional methodology applied the principle of gradual progression, beginning with practice to consolidate the concepts learned in the initial lessons before moving on to more complex activities and material. Each participant was allowed to progress at his or her own pace. Learning was based on imitation and guided execution of judo-specific skill patterns [51].

Table 1. Contents and temporal distribution of the adapted judo sessions.

Content	Time (min)
Different types of movements and falling techniques (from walking in all directions to change of direction activities, from stable movements to unstable movements).	15–20
Judo analytical techniques and judo games (progressively increasing body contact with games, simplifying movements to focus on essential judo movements).	25–30
Ground control techniques and throws (add technical details incrementally to already known movements, progression from repetitive movements to those more relevant to the understanding and purpose of judo).	25–30
Repetitions of basic movements in different directions and planes (pulling, pushing, holding, lifting).	20–30

The chosen learning method was imitation, where the instructors exposed the techniques and guided the practice. Very marked routines were based on brief and clear instructions, speaking calmly and with a firm voice. The instructions were objective and refrained from using figurative language or irony. Spontaneous and unexpected behavior changes were monitored and redirected by the judo instructors. They were aware that each participant needed their own time. Instructions were given repetitively and used a wide spectrum of senses, not just verbal signals. The isolated use of sensory instructions, one at a time, can aid perception. For example, the instructor can demonstrate physically with verbal instructions and one time without speaking. At the beginning of the program, pictograms were used, but they were stopped because it was considered that it was not necessary.

2.3.1. ALPHA-Fitness Battery

The ALPHA-fitness battery [38] administered in this study is a well-known instrument for measuring health-related physical fitness. This battery consists of various field tests and is suitable for use with children and adolescents. This study used the high-priority variant of the test, which omits skin-fold measurement (triceps and subscapularis). The version used here included the following tests: (1) the 20 m Shuttle Run Test to assess cardiorespiratory fitness; (2) the handgrip strength test; (3) the standing long jump tests to assess musculoskeletal fitness; (4) BMI; and (5) waist circumference. Verbal instructions and demonstrations were given to the participants before each test element until they understood the tasks. The instructors always attempted to motivate all participants [52]. All the tests were carried out in the space that hosted the judo sessions, guaranteeing the necessary space and safety conditions.

The participants' aerobic capacity was measured using their 20 m Shuttle Run Test scores. Because some of the children in this study had difficulties understanding the instructions, they were sometimes accompanied during their run by the test observers. The test required children to run between two cones placed 20 m apart at a pace set by sound signals. The test ended when the child could not reach the next cone or gave up because of fatigue. The final distance the children ran was recorded. Musculoskeletal fitness was measured via the muscle strength in their hands and legs. Hand strength was measured by asking participants to apply maximal pressure with their dominant hand on the handgrip dynamometer (TKK 5101; Takey, Tokyo, Japan). The device was adjusted to fit the size of each participant's hand. The participants performed the test standing up with their dominant arm extended, and the best score of two attempts was recorded. The standing long jump test was used to assess the explosive strength of the lower limbs. The children were asked to jump as far as possible on two feet from a standing position. The score for this test was the distance jumped in centimeters on the best jump of two attempts. BMI was calculated as weight (kg) divided by the height squared (m^2). Participants' weights and heights were measured using a standard protocol.

2.3.2. A Non-Exercise Equation to Estimate CRF

In order to estimate VO_2max (eVO_2max), we recorded data on each participant's age, waist circumference (WC) and baseline heart rate ($HR_{baseline}$). In addition, the legal guardians of the participants were asked about the frequency and intensity of their children's physical activity and the time spent on it. These data were then analyzed using the modified version [46] of the physical activity index (PAI), which was previously published by Kurtze et al. [53]. The first question on the questionnaire was, "How many times do you do physical activity each week?" Respondents choose one of the following answers: 0 = never or less than one day a week; 1 = at least one day a week; 2 = two to three days a week; 3 = almost every day. The second question was, "How much time do you spend on each session?" Respondents choose one of the following answers: 1 = less than 30 min; 1.5 = more than 30 min. The third question was, "What is the intensity of the physical activity you do?" Respondents can choose among the following answers: 0 = very soft or soft; 5 = heavy breathing and sweating; 10 = maximum intensity, near exhaustion.

In order to gather data on the $HR_{baseline}$, a finger pulse oximeter (Lifesense LS1-9R, Nonin Medical Inc., Plymouth, MN, United States) was provided to the family of each participant. Family members were instructed to measure for a minute immediately after waking up in the morning for at least four days. The average of the four-day $HR_{baseline}$ results was entered into the formula before and after the intervention.

The participants' waist circumference (WC) was evaluated in accordance with previously published instructions [54]. Briefly, WC was measured with participants standing with their feet shoulder-width apart using a standard non-elastic anthropometric tape measure. WC measurements were taken to the nearest 0.1 cm, midway between the lower rib and the iliac crest, near the level of the umbilicus, after a gentle exhalation. A trained researcher made two measurements and calculated the mean unless the two values differed by more than 0.5 cm, in which case one more measurement was taken. Waist circumference and WHT.5R were used for analysis.

2.4. Statistical Analysis

Descriptive testing data are shown as mean ± standard deviation. The subtests of the ALPHA-fitness battery that require a maximum effort or maximum performance (20 m Shuttle Run Test, handgrip strength, and the standing broad jump) were each recorded twice in a single testing session (each time the best score of two attempts was recorded), except for the 20 m Shuttle Run Test, which was repeated after 48 h. In order to verify test-retest reliability, the Intraclass Correlation Coefficient ICC (bidirectional mixed model, absolute agreement, single measures) was used. ICC values of less than 0.5, from 0.5 to 0.75, from 0.75 to 0.9, and greater than 0.90 indicate poor, moderate, good, and excellent reliability, respectively [55]. ICC calculations were carried out using the Statistical Package for Social Science, version 24.0 (SPSS, Inc., Chicago, IL, USA).

Changes within and between groups were analyzed using linear mixed models for repeated measure designs when all assumptions were met. Normality of the residuals was analyzed using the Shapiro–Wilk test for every variable and revealed no deviations from a normal distribution for WC and WHT.5R. However, $HR_{baseline}$ and eVO_2max residuals were not normal. Homoscedasticity was checked by plotting the residuals-predicted value [56], and we found that residuals were constant across the predicted values for most of the derived variables but not for $HR_{baseline}$ or eVO_2max. Therefore, we employed a nonparametric ANOVA-type statistical test for the latter variables. The alpha level was set at $p < 0.05$ for all the analyses.

We employed the module GAMLj for the linear mixed model analyses. This module uses the R formulation of random effects, as implemented by the lme4 R package in jamovi software [57]. GAMLj estimates variance components with restricted (residual) maximum likelihood, which, unlike earlier maximum likelihood estimation, produces unbiased estimates of variance and covariance parameters. The inter-subject group factor (EXP or CON), the intrasubject time factor (PRE and POST tests), and the interaction

(GROUP × TIME) were set as fixed effects, and participants' intercepts were set as a random effect. Changes were evaluated using the β coefficients and a corresponding 95% confidence interval (CI), representing a non-standardized effect size. Between-group changes were assessed using the estimated parameter with a 95% CI of the interaction between the fixed effect of the model. When a significant interaction was detected, we carried out a simple effects analysis of the within-group effect of the time of measurement. The standardized mean difference between PRE and POST was calculated as the mean change score divided by the SD of the change score, termed Cohen's dz [58], and it was corrected by Hedges' g to account for the small sample sizes. Cohen's dz effect was presented with a 90% CI and qualitatively interpreted as trivial if dz < 0.20, small if 0.20 ≤ dz < 0.50, medium if 0.50 ≤ dz < 0.80, large if 0.80 ≤ dz < 1.30 and very large if dz ≥ 1.30 [59].

The effect of the intervention on $HR_{baseline}$ and eVO_2max was analyzed using nparLD (nonparametric analysis of longitudinal data in factorial experiments) with the R software package [60]. This package calculates nonparametric ANOVA-type statistics (group × time) and uses ranks to calculate relative marginal effects. It was chosen because, unlike traditional nonparametric tests, this test provides information on the effect of each factor and the interaction between them. When a significant interaction was detected, we carried out a simple effects analysis of the within-group effect of the time of measurement. Within-subject changes were analyzed through stochastic superiority ($A_{post-pre}$), which represents the probability that a randomly selected score from the post-intervention will be greater than a randomly selected score from the pre-intervention. Probability values equal to or higher than 0.56, 0.64 and 0.71 when approaching one or values equal to or lower than 0.44, 0.36 and 0.29 when approaching 0 for $A_{post-pre}$ were regarded as small, medium and large values, respectively [61].

3. Results

Table 2 shows the descriptive statistics for the ALPHA-fitness battery of tests and the ICC, corresponding to the ICC test-retest values. All ICC scores on the tests requiring maximum effort were poor (<0.5): 20 m Shuttle Run Test (ICC = 0.21), handgrip strength (0.16) and the standing broad jump (0.48). Therefore, it was decided not to use the results of these tests because inconsistency in the results gathered with the sample would make it difficult to interpret any possible changes during data analysis.

Table 2. Descriptive statistics and reliability of the ALPHA-fitness battery of tests.

TEST	Mean (±Standard Deviation)	ICC
20 m Shuttle Run Test	3.45 periods (±1.75)	0.21
Handgrip strength	15.87 kg (±4.95)	0.16
Standing broad jump	127 cm (±0.33)	0.48
BMI	22.23 kg/m^2 (±2.33)	0.98
Waist circumference	72.95 cm (±6.34)	0.99

There was no difference before the intervention between the study groups in age, height, weight, WC, WHT.5R, $HR_{baseline,}$ and eVO_2max. Table 3 presents the effects of the fixed factors obtained after analyzing the WC and the WHT.5R using the mixed linear model. Effects of time of measurement and time × group interaction were found for both variables. In the analysis of the simple effects, we found that the EXP group reduced their WC (PRE: 72.5 ± 7.5 cm vs. POST: 70.6 ± 6.9 cm; coefficient: −1.86 cm, 95%CI [−2.63; −1.09]; t38 = −4.90 , $p < 0.001$; dz = −0.98, 90% CI [−1.23; −0.81], large), whereas there were no changes in the CON group (PRE: 73.5 ± 4.9 cm vs. POST: 73.8 ± 5.1 cm; coefficient: 0.32 cm, 95%CI [−0.49, 1.23], t38 = 0.79, $p = 0.433$, dz = 0.19, 90% CI [0.07, 0.33], negligible). However, simple effects analysis showed a reduction in WHT.5R in both the EXP group (PRE: 0.60 ± 0.05 vs. POST: 0.58 ± 0.05; coefficient: −0.024, 95%CI [−0.030; −0.019]; t38 = −7.83, $p < 0.001$; dz = −1.64, 90% CI [−2.04; −1.38], very large) and the CON

group (PRE: 0.61 ± 0.04 vs. POST: 0.61 ± 0.04; coefficient: −0.008, 95%CI [−0.015, −0.002], t38 = −2.51, p = 0.016, dz = −0.58, 90% CI [−0.79, −0.42], medium).

Table 3. Fixed effects of the variables WC and WHT.5R.

Variable	Effect	Estimate	Lower 95% CI	Upper 95% CI	t_{38}	p
Waist Circumference (cm)	(Intercept)	72.59	70.67	74.51	73.94	<0.001
	CON vs. EXP	2.08	−1.76	5.93	1.06	0.295
	POST vs. PRE	−0.77	−0.23	−1.31	−2.80	0.008
	CON vs. EXP POST vs. PRE	2.17	1.10	3.25	3.95	<0.001
WHT.5R ($m \times m^{-1}$)	(Intercept)	0.598	0.584	0.611	87.23	<0.001
	CON vs. EXP	0.022	−0.005	0.049	1.62	0.113
	POST vs. PRE	−0.016	−0.020	−0.012	−7.21	<0.001
	CON vs. EXP POST vs. PRE	0.016	0.007	0.025	3.58	<0.001

Figure 1 shows the effects of the fixed factors on eVO_2max and $HR_{baseline}$ after non-parametric analysis with ANOVA-type statistical analysis. There was an effect of the time of measurement on both variables, and there was a time × group interaction. Simple effects analysis showed an increase in eVO2max in the EXP group (PRE: 53.5 ± 7.4 mL/kg/min vs. POST: 55.2 ± 7.5 mL/kg/min; $F_{1,\infty}$ = 73.96, p < 0.001; $A_{post\text{-}pre}$ = 66.6%, medium), whereas there were no changes in the CON group (PRE: 54.2 ± 6.2 mL/kg/min vs. POST: 54.2 ± 6.2 mL/kg/min; $F_{1,\infty}$ = 0.26, p = 0.609; $A_{post\text{-}pre}$ = 51.4%, negligible). However, there were reductions in $HR_{baseline}$ in both EXP (PRE: 73.60 ± 7.0 ppm vs. POST: 68.3 ± 4.4 ppm; $F_{1,\infty}$ = 32.50, p < 0.001) and CON (PRE: 72.3 ± 7.8 ppm vs. POST: 70.6 ± 5.5; $F_{1,\infty}$ = 32.50, p = 0.018), although the effect size was greater in EXP ($A_{post\text{-}pre}$ = 28.0%, medium) than CON ($A_{post\text{-}pre}$ = 45.6%, negligible).

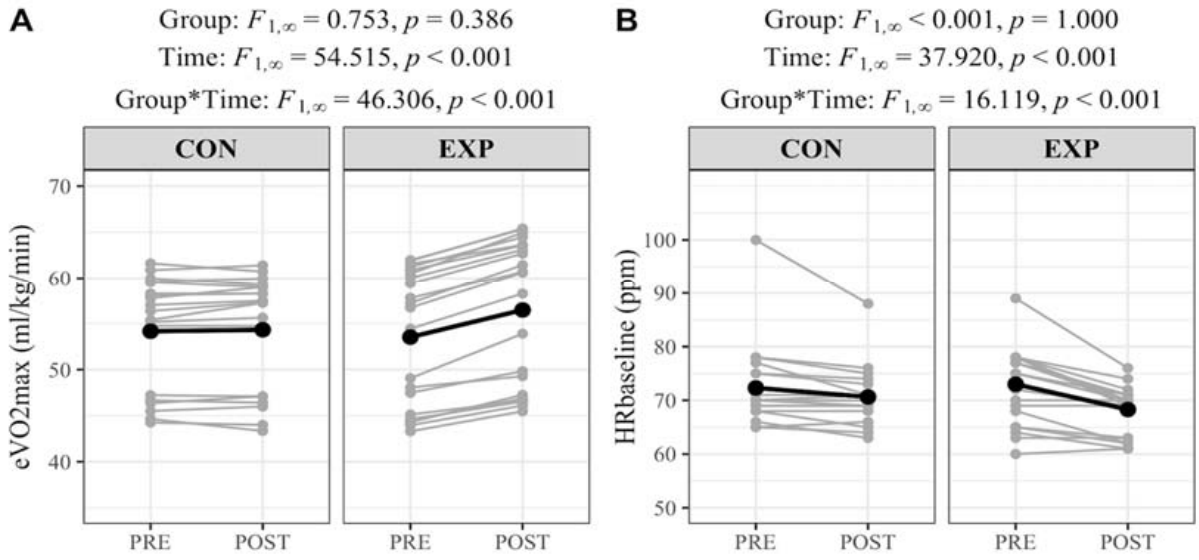

Figure 1. Individual responses and effects of fixed factors on $eVO2_{max}$ and $HR_{baseline}$ before and after the intervention.

4. Discussion

This study investigated the effects of an adapted judo program on the health-related physical fitness of a group of children with ASD. Participation in the program was linked to greater improvements in body composition parameters (i.e., waist and WHT.5R) and cardiorespiratory fitness (i.e., eVO_2max) in the experimental group than in the control

group. The data on muscle strength, evaluated using the Alpha-fitness battery in the pretest, showed a very low degree of reliability, so it was decided not to carry out a post-test due to the difficulty that the interpretation of the data would entail.

Previous studies have discussed how participation in sports programs can improve the physical fitness of children with ASD. For example, a meta-analysis by Healy et al. (2018) [22] highlights that experimental groups tended to outperform control groups, with a large effect (d = 0.81) in muscular strength and endurance outcomes, although they underscored that best results require longer interventions. The meta-analysis and systematic review by Sam et al. [23] found that children and adolescents with ASD tend to show improvements in physical fitness, exercise mastery and social competence after participating in exercise programs. There is a considerable history of studies examining the effects of specific exercise or sports programs on the health-related fitness of children with ASD. In one study, aquatic exercise programs were effective at improving physical conditioning [62,63]. More recent studies in this regard have detailed the effects of participation in a high-intensity exercise program to improve physical fitness [64], and the participation in both structured physical activities [65] and individualized fitness programs [66]. A five-month rhythmic gymnastics intervention for children with intellectual disabilities [67] obtained similar results to those of the present study in improving cardiorespiratory fitness. Another long-term program in which a treadmill exercise routine was carried out over nine months [68] yielded an improvement in body composition similar to our results. However, these improvements do not appear to be duration-dependent as long as a minimum duration of eight weeks is reached. Shorter interventions using different sports have also arrived at results consistent with our study [62,63,63]. For instance, mini-basketball has also been used effectively to improve the physical fitness of preschool children with autism.

Low levels of cardiorespiratory fitness (CRF) have been identified as a potential risk factor for cardiovascular disease (CVD) and all-cause mortality. Conversely, substantial health benefits can be gained through improved CRF, which can be achieved via physical activity and exercise [45]. In this regard, CRF is viewed as an important marker of cardiovascular health and has even been recommended as a new vital sign by the American Heart Association [45]. Indeed, there is evidence that early intervention and prevention strategies that target youth CRF might be associated with maintaining positive health parameters in later life [69]. Furthermore, CRF is an important marker of physical and mental health and academic achievement in youth [49]. Therefore, family members, educators and health professionals caring for children with ASD should evaluate and implement strategies to improve CRF, including participation in adapted judo programs.

Meanwhile, experiences with other interventions that did not limit their focus to any specific sport also reinforce the results of this study. Such programs usually feature physical exercise interventions with a very similar structure to that of judo sessions. In one study, a high-intensity exercise intervention with alternating rest intervals [64], in which squats, jumping jacks and bear crawls were performed in stationary circuit mode, was linked to improvements in CRF and trunk and limb strength. Arslan et al. (2020) [65] also carried out a structured exercise intervention that included balancing and strength exercises, walking and jumps, leading to significant improvements in running speed and agility, balance, standing long jump performance, reaction times, grip strength and flexibility.

Elsewhere, an intervention using individualized fitness programs [66] also improved overall strength and BMI for half of the participants, although the mean BMI did not change significantly. Srinivasan et al. [34] suggested that BMI, waist circumference and skin-fold thickness measurements could be used to assess changes in body composition as an indicator of health during and after exercise interventions in children with ASD. These authors also suggested quantitative measures of physical activity that included heart rate monitoring and accelerometry, as well as qualitative measures of physical activity that included diaries, logs, and questionnaires completed by parents and caregivers. In addition, it has been pointed out that field tests are preferable to laboratory tests when it comes to measuring the physical fitness of children with ASD [35]. It is important to note that using

BMI as a measure can lead to biases that affect the final result. BMI calculations consider weight and height, but changes in weight, especially at early ages, may be due to changes in body composition that do not necessarily imply fat mass gain. For this reason, in our study, we have used the WHT.5R index, which is independent of height and has been suggested as the best WC-derived index associated with metabolic health indicators [43]. In our study, a group effect was found as a function of the time of measurement (meaning a group × time interaction) on the WC and the WHT.5R. Specifically, in the EXP group, WC saw a reduction with a large effect size, and the results for WHT.5R indicated a very large effect size, whereas in the CON group, there was no change in WC and only a moderate reduction in WHT.5R.

It is well-established that judo improves health-related physical fitness in children and adolescents [70]. Apart from its positive effects on health and physical fitness, it has also been associated with psychological and social improvements [71]. The specific focus of this study is on the health-related physical fitness improvements that can come from participating in judo. Numerous studies detailing long-term interventions in typically developing individuals have reported improvements. Several studies examining the influence of one-year judo programs have pointed to improvements in various physical fitness and motor domains such as hand strength, flexibility, general coordination [72], the quality of body posture, balance and lower limb muscle strength impulse [73]. Other investigations have compared the benefits of judo with those of other sports [74,75]. A more recent but shorter study [76] found significant improvements in CRF and body composition among an experimental group of obese children who had participated in a recreational judo program than in a control group. Physical exercise interventions that replicate situations similar to judo sessions have generally been shown to be effective in improving the health of children with ASD. Such exercise sessions are characterized by alternating high- and low-intensity phases, individualized attention, respect for the pace of each participant, explicit verbal and visual instructions, tactile guidance, continuous repetitions and feedback for reinforcement.

Prior research on the effects of judo on the physical fitness of individuals with ASD is somewhat scarce, and the existing studies have always used a much shorter intervention time. The focuses of these earlier studies have mainly been on analyzing the levels of adherence to the adapted judo program, achieving an increase in the volume of physical activity from moderate to vigorous [24], measuring the levels of acceptance and rates of enjoyment or inspiring a solid desire to continue with the activity [32]. Elsewhere, researchers have sought to gauge the decrease in stress and cortisol levels among young people with ASD who do judo [77]. The present study has addressed evidence of the benefits of adapted sport programs employing a relatively large sample compared to similar studies. The study used a long-term intervention and a research design featuring a control group to improve the integrity of the results. Despite the barriers found to measuring physical condition and delivering judo sessions in children with ASD, the present study showed safe and valid protocols that pretend to encourage education (i.e., teachers and pedagogues) and health professionals (i.e., physiotherapists, occupational therapists and sport coaches) to work in a multidisciplinary and interdisciplinary way to promote physical exercise and its linked benefits to this population.

The most important limitation of this study lies in the impossibility of repeating the strength and aerobic endurance tests in the post-test. The results of <0.5 ICC forced us to rule out performing a post measurement. The ALPHA-fitness battery includes tests that have been used regularly in individuals with ASD, but some authors have warned of issues that can emerge when administering the test, depending on the level of IQ of the participants [33]. If the tests require maximum effort or performance, uncertainties arise. Those responsible for administering the tests are never sure whether the participants have jumped as high as they are capable of, whether they have applied all of their strength in the handgrip test, or whether they have continued the 20 m Shuttle Run Test as long as they were able. The use of VO_2max has been suggested as an indicator of cardiorespiratory fitness and as a very powerful predictor of general health [45]. The use of a "model without

exercise" was considered the best way to estimate the VO_2max of the sample of this study. This model uses easily accessible measures such as age, gender, resting heart rate, self-reported level of physical activity and body composition [46], all of which are factors that have shown their influence on the mechanisms responsible for VO_2max. The model is validated and has a very large sample that lends it a great deal of credibility. On the other hand, in the field of body composition, BMI has been discarded as an indicator of cardio-metabolic health, and the WHT.5R index has been used instead [43], as it is considered the most suitable instrument in these cases. These two indicators showed significantly greater improvements in both cardiorespiratory fitness and cardio-metabolic health in the experimental group than in the control group.

5. Conclusions

The most important conclusion of this study is that it has shown that an adapted judo program for children with ASD can improve the cardio-metabolic health and cardiorespiratory fitness of its participants. The study also highlights the difficulties involved in applying physical fitness tests that involve maximum effort or performance in individuals with ASD, because of doubts about their reproducibility.

The study provides additional support for the monitoring of health-related physical fitness in individuals with ASD through methods that estimate the results with easily accessible data such as age, sex, anthropometric data, HR and the self-reported level of physical activity. Such methods facilitate data gathering and help overcome the uncertainties generated by the application of physical tests to this type of population.

These health improvements are further evidence in favor of the use of judo programs as a complementary intervention to improve cardiovascular risk level and physical fitness in children with ASD. Further studies should investigate the dose-response relationships of judo training with the aim of reducing cardiovascular risk and improving fitness in this population.

Author Contributions: J.M., E.P. and E.C. conceptualised the study, analysed the data and wrote the manuscript. D.H.F. assisted with conceptualising the study and writing/editing the manuscript. V.G. assisted with data collection and editing the manuscript. E.P. assisted with data collection, and writing/editing the manuscript. A.M.G. assisted with interpretation of the results and editing the manuscript. M.G.-B. conceptualised the study, analysed the data and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: All the protocols carried out within this research, including the treatment of the participants' personal information, were done in accordance with the requirements of the 1975 Declaration of Helsinki and the subsequent revisions. This study received the approval of the Research Ethics Committee of Universitat Ramon Llull under file number CER URL_2019_2020_003, and the trial was registered on Clinicaltrials.gov (NCT04523805).

Informed Consent Statement: The participants' parents or legal guardians signed informed consent documents, and the children themselves signed a consent document that explained the program's plan and objectives.

Data Availability Statement: Data available at https://doi.org/10.6084/m9.figshare.20465337.

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References

1. Sit, C.H.; Yu, J.J.; Wong, S.H.; Capio, C.M.; Masters, R. A school-based physical activity intervention for children with developmental coordination disorder: A randomized controlled trial. *Res. Dev. Disabil.* **2019**, *89*, 1–9. [CrossRef]
2. Bull, F.C.; Al-Ansari, S.S.; Biddle, S.; Borodulin, K.; Buman, M.P.; Cardon, G.; Carty, C.; Chaput, J.-P.; Chastin, S.; Chou, R.; et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med.* **2020**, *54*, 1451–1462. [CrossRef]
3. World Health Organization. *Global Recommendations on Physical Activity for Health*; World Health Organization: Geneva, Switzerland, 2010.
4. Inchley, J.; Currie, D.; Jewell, J.; Breda, J.; Barnekow, V. *Adolescent Obesity and Related Behaviours*; World Health Organisation, Regional Office for Europe: Geneva, Switzerland, 2017.
5. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders: DSM-5*, 5th ed.; American Psychiatric Association: Arlington, VA, USA, 2013.
6. Pan, C.-Y.; Tsai, C.-L.; Chu, C.-H.; Sung, M.-C.; Ma, W.-Y.; Huang, C.-Y. Objectively measured physical activity and health-related physical fitness in secondary school-aged male students with autism spectrum disorders. *Phys. Ther.* **2016**, *96*, 511–520. [CrossRef]
7. Gregor, S.; Bruni, N.; Grkinic, P.; Schwartz, L.; McDonald, A.; Thille, P.; Gabsion, S.; Gibson, B.E.; Jachyra, P. Parents' perspectives of physical activity participation among Canadian adolescents with Autism Spectrum Disorder. *Res. Autism Spectr. Disord.* **2018**, *48*, 53–62. [CrossRef]
8. Jachyra, P.; Renwick, R.; Gladstone, B.; Anagnostou, E.; Gibson, B.E. Physical activity participation among adolescents with autism spectrum disorder. *Autism* **2021**, *25*, 613–626. [CrossRef]
9. Must, A.; Phillips, S.M.; Carol, C.; Bandini, L.G. Barriers to physical activity in children with autism spectrum disorders: Relationship to physical activity and screen time. *J. Phys. Act. Health* **2015**, *12*, 529. [CrossRef]
10. Obrusnikova, I.; Cavalier, A.R. Perceived barriers and facilitators of participation in after-school physical activity by children with autism spectrum disorders. *J. Dev. Phys. Disabil.* **2011**, *23*, 195–211. [CrossRef]
11. Healy, S.; Haegele, J.A.; Grenier, M.; Garcia, J.M. Physical activity, screen-time behavior, and obesity among 13-year olds in Ireland with and without autism spectrum disorder. *J. Autism Dev. Disord.* **2017**, *47*, 49–57. [CrossRef] [PubMed]
12. McCoy, S.M.; Jakicic, J.M.; Gibbs, B.B. Comparison of obesity, physical activity, and sedentary behaviors between adolescents with autism spectrum disorders and without. *J. Autism Dev. Disord.* **2016**, *46*, 2317–2326. [CrossRef] [PubMed]
13. Cutts, B.B.; Darby, K.J.; Boone, C.G.; Brewis, A. City structure, obesity, and environmental justice: An integrated analysis of physical and social barriers to walkable streets and park access. *Soc. Sci. Med.* **2009**, *69*, 1314–1322. [CrossRef]
14. Hassani, F.; Shahrbanian, S.; Shahidi, S.H.; Sheikh, M. Playing games can improve physical performance in children with autism. *Int. J. Dev. Disabil.* **2022**, *68*, 219–226. [CrossRef] [PubMed]
15. Badura, P.; Geckova, A.M.; Sigmundova, D.; van Dijk, J.P.; Reijneveld, S.A. When children play, they feel better: Organized activity participation and health in adolescents. *BMC Public Health* **2015**, *15*, 1–8. [CrossRef]
16. Morales, J.; Fukuda, D.H.; Garcia, V.; Pierantozzi, E.; Curto, C.; Martínez-Ferrer, J.O.; Gomez, A.M.; Carballeira, E.; Guerra-Balic, M. Behavioural Improvements in Children with Autism Spectrum Disorder after Participation in an Adapted Judo Programme Followed by Deleterious Effects during the COVID-19 Lockdown. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8515. [CrossRef]
17. Serrada-Tejeda, S.; Santos-del-Riego, S.; May-Benson, T.A.; Pérez-de-Heredia-Torres, M. Influence of Ideational Praxis on the Development of Play and Adaptive Behavior of Children with Autism Spectrum Disorder: A Comparative Analysis. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5704. [CrossRef] [PubMed]
18. Bremer, E.; Crozier, M.; Lloyd, M. A systematic review of the behavioural outcomes following exercise interventions for children and youth with autism spectrum disorder. *Autism* **2016**, *20*, 899–915. [CrossRef] [PubMed]
19. Howells, K.; Sivaratnam, C.; May, T.; Lindor, E.; McGillivray, J.; Rinehart, N. Efficacy of Group-Based Organised Physical Activity Participation for Social Outcomes in Children with Autism Spectrum Disorder: A Systematic Review and Meta-analysis. *J. Autism Dev. Disord.* **2019**, *49*, 3290–3308. [CrossRef]
20. Colombo-Dougovito, A. Successful evidence-based practices for autism spectrum disorder and their use for the development of motor skills in physical education. *Palaestra* **2015**, *29*, 34–42.
21. Crucitti, J.; Hyde, C.; Stokes, M.A. Hammering that nail: Varied praxis motor skills in younger autistic children. *J. Autism Dev. Disord.* **2020**, *50*, 3253–3262. [CrossRef] [PubMed]
22. Healy, S.; Nacario, A.; Braithwaite, R.E.; Hopper, C. The Effect of Physical Activity Interventions on Youth with Autism Spectrum Disorder: A Meta-Analysis. *Autism Res.* **2018**, *11*, 818–833. [CrossRef]
23. Sam, K.-L.; Chow, B.-C.; Tong, K.-K. Effectiveness of exercise-based interventions for children with autism: A systematic review and meta-analysis. *Int. J. Learn. Teach.* **2015**, *1*, 98–103. [CrossRef]
24. Garcia, J.M.; Leahy, N.; Rivera, P.; Renziehausen, J.; Samuels, J.; Fukuda, D.H.; Stout, J.R. Brief Report: Preliminary Efficacy of a Judo Program to Promote Participation in Physical Activity in Youth with Autism Spectrum Disorder. *J. Autism Dev. Disord.* **2019**, *50*, 1418–1424. [CrossRef]

25. Bell, A.; Allen, M. Using Martial Arts to Address Social and Behavioral Functioning in Children and Adolescents With Autism Spectrum Disorder. *Ther. Recreat. J.* **2016**, *50*, 176–181.
26. Sarabzadeh, M.; Azari, B.B.; Helalizadeh, M. The effect of six weeks of Tai Chi Chuan training on the motor skills of children with Autism Spectrum Disorder. *J. Bodyw. Mov. Ther.* **2019**, *23*, 284–290. [CrossRef]
27. Kim, Y.; Todd, T.; Fujii, T.; Lim, J.-C.; Vrongistinos, K.; Jung, T. Effects of Taekwondo intervention on balance in children with autism spectrum disorder. *J. Exerc. Rehabil.* **2016**, *12*, 314–319. [CrossRef]
28. Bahrami, F.; Movahedi, A.; Marandi, S.M.; Abedi, A. Kata techniques training consistently decreases stereotypy in children with autism spectrum disorder. *Res. Dev. Disabil.* **2012**, *33*, 1183–1193. [CrossRef]
29. Movahedi, A.; Bahrami, F.; Marandi, S.M.; Abedi, A. Improvement in social dysfunction of children with autism spectrum disorder following long term Kata techniques training. *Res. Autism Spectr. Disord.* **2013**, *7*, 1054–1061. [CrossRef]
30. Pečnikar Oblak, V.; Karpljuk, D.; Vodičar, J.; Simenko, J. Inclusion of people with intellectual disabilities in judo: A systematic review of literature. *Arch. Budo* **2020**, *16*, 245–260.
31. Rivera, P.; Renziehausen, J.; Garcia, J.M. Effects of an 8-Week Judo Program on Behaviors in Children with Autism Spectrum Disorder: A Mixed-Methods Approach. *Child Psychiatry Hum. Dev.* **2020**, *52*, 129–140. [CrossRef]
32. Tomey, K.L. *Effects of a Modified Judo Program on Psychosocial Factors in Typically Developing and Children with Autism Spectrum Disorder: A Mixed-Methods Study*; University of Central Florida: Orlando, FL, USA, 2017. Available online: https://stars.library.ucf.edu/honorstheses/252 (accessed on 1 December 2022).
33. Wouters, M.; Evenhuis, H.M.; Hilgenkamp, T.I.M. Systematic review of field-based physical fitness tests for children and adolescents with intellectual disabilities. *Res. Dev. Disabil.* **2017**, *61*, 77–94. [CrossRef]
34. Srinivasan, S.M.; Pescatello, L.S.; Bhat, A.N. Current perspectives on physical activity and exercise recommendations for children and adolescents with autism spectrum disorders. *Phys. Ther.* **2014**, *94*, 875–889. [CrossRef]
35. Fernhall, B.; Pitetti, K.H.; Vukovich, M.D.; Stubbs, N.; Hensen, T.; Winnick, J.P.; Short, F.X. Validation of cardiovascular fitness field tests in children with mental retardation. *Am. J. Ment. Retard.* **1997**, *102*, 602–612. [CrossRef]
36. Coffey, C.; Sheehan, D.; Faigenbaum, A.D.; Healy, S.; Lloyd, R.S.; Kinsella, S. Comparison of fitness levels between elementary school children with autism spectrum disorder and age-matched neurotypically developing children. *Autism Res.* **2021**, *14*, 2038–2046. [CrossRef]
37. Pace, M.; Bricout, V.-A. Low heart rate response of children with autism spectrum disorders in comparison to controls during physical exercise. *Physiol. Behav.* **2015**, *141*, 63–68. [CrossRef] [PubMed]
38. Ruiz, J.R.; Castro-Piñero, J.; España-Romero, V.; Artero, E.G.; Ortega, F.B.; Cuenca, M.M.; Jimenez-Pavon, D.; Chillon, P.; Girela-Rejon, M.J.; Mora, J.; et al. Field-based fitness assessment in young people: The ALPHA health-related fitness test battery for children and adolescents. *Br. J. Sports Med.* **2011**, *45*, 518–524. [CrossRef] [PubMed]
39. Tejero-Gonzalez, C.M.; Martinez-Gomez, D.; Bayon-Serna, J.; Izquierdo-Gomez, R.; Castro-Pinero, J.; Veiga, O.L. Reliability of the ALPHA health-related fitness test battery in adolescents with Down syndrome. *J. Strength Cond. Res.* **2013**, *27*, 3221–3224. [CrossRef]
40. Ortega, F.B.; Cadenas-Sánchez, C.; Sánchez-Delgado, G.; Mora-González, J.; Martínez-Téllez, B.; Artero, E.G.; Castro-Piñero, J.; Labayen, I.; Chillon, P.; Lof, M.; et al. Systematic review and proposal of a field-based physical fitness-test battery in preschool children: The PREFIT battery. *Sport. Med.* **2015**, *45*, 533–555. [CrossRef]
41. Prentice, A.M.; Jebb, S.A. Beyond body mass index. *Obes. Rev.* **2001**, *2*, 141–147. [CrossRef]
42. Ashwell, M.; Gunn, P.; Gibson, S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: Systematic review and meta-analysis. *Obes. Rev.* **2012**, *13*, 275–286. [CrossRef]
43. Nevill, A.M.; Duncan, M.J.; Myers, T. BMI is dead; long live waist-circumference indices: But which index should we choose to predict cardio-metabolic risk? *Nutr. Metab. Cardiovasc. Dis.* **2022**. [CrossRef]
44. Vanhees, L.; Lefevre, J.; Philippaerts, R.; Martens, M.; Huygens, W.; Troosters, T.; Beunen, G. How to assess physical activity? How to assess physical fitness? *Eur. J. Prev. Cardiol.* **2005**, *12*, 102–114. [CrossRef]
45. Ross, R.; Blair, S.N.; Arena, R.; Church, T.S.; Després, J.-P.; Franklin, B.A.; Haskell, W.L.; Kaminsky, L.A.; Levine, B.D.; Lavie, C.J.; et al. Importance of assessing cardiorespiratory fitness in clinical practice: A case for fitness as a clinical vital sign: A scientific statement from the American Heart Association. Circulation. *Am. Heart. Assoc.* **2016**, *134*, e653–e699. [CrossRef]
46. Nes, B.M.; Janszky, I.; Vatten, L.J.; Nilsen, T.I.; Aspenes, S.T.; Wisløff, U. Estimating V· O 2peak from a nonexercise prediction model: The HUNT Study, Norway. *Med. Sci. Sports Exerc.* **2011**, *43*, 2024–2030. [CrossRef]
47. Jurca, R.; Jackson, A.S.; LaMonte, M.J.; Morrow, J.R., Jr.; Blair, S.N.; Wareham, N.J.; Haskell, W.L.; van Mechelen, W.; Church, T.S.; Jakicic, J.M.; et al. Assessing cardiorespiratory fitness without performing exercise testing. *Am. J. Prev. Med.* **2005**, *29*, 185–193. [CrossRef] [PubMed]
48. Laukkanen, J.A.; Laaksonen, D.; Lakka, T.A.; Savonen, K.; Rauramaa, R.; Mäkikallio, T.; Kurl, S. Determinants of cardiorespiratory fitness in men aged 42 to 60 years with and without cardiovascular disease. *Am. J. Cardiol.* **2009**, *103*, 1598–1604. [CrossRef]
49. Raghuveer, G.; Hartz, J.; Lubans, D.R.; Takken, T.; Wiltz, J.L.; Mietus-Snyder, M.; Perak, A.M.; Pietris, N.; Takken, T.; Wiltz, J.L. Cardiorespiratory fitness in youth: An important marker of health: A scientific statement from the American Heart Association. Circulation. *Am. Heart. Assoc.* **2020**, *142*, e101–e118. [CrossRef] [PubMed]
50. Wang, Y.; Chen, S.; Lavie, C.J.; Zhang, J.; Sui, X. An overview of Non-exercise estimated cardiorespiratory fitness: Estimation equations, cross-validation and application. *J. Sci. Sport Exerc.* **2019**, *1*, 38–53. [CrossRef]

51. Dopico, X.; Iglesias-Soler, E.; Carballeira, E. Classification of judo motor skills: Tactical and motor criteria approach. *Arch. Budo* **2014**, *10*, 75–83.
52. Waninge, A.; van der Weide, W.; Evenhuis, I.J.; van Wijck, R.; van der Schans, C.P. Feasibility and reliability of body composition measurements in adults with severe intellectual and sensory disabilities. *J. Intellect. Disabil. Res.* **2009**, *53*, 377–388. [CrossRef] [PubMed]
53. Kurtze, N.; Rangul, V.; Hustvedt, B.-E.; Flanders, W.D. Reliability and validity of self-reported physical activity in the Nord-Trøndelag Health Study—HUNT 1. *Scand. J. Public Health* **2008**, *36*, 52–61. [CrossRef]
54. Moreno, L.A.; Joyanes, M.; Mesana, M.I.; González-Gross, M.; Gil, C.M.; Sarría, A.; Gutierrez, A.; Garaulet, M.; Perez-Prieto, R.; Bueno, M.; et al. Harmonization of anthropometric measurements for a multicenter nutrition survey in Spanish adolescents. *Nutrition* **2003**, *19*, 481–486. [CrossRef] [PubMed]
55. Koo, T.K.; Li, M.Y. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J. Chiropr. Med.* **2016**, *15*, 155–163. [CrossRef] [PubMed]
56. Santos, J.; da Motta, J. Residual analysis for linear mixed models. *Biometr. J. J. Math. Methods Biosci.* **2007**, *49*, 863–875. [CrossRef] [PubMed]
57. Jamovi. *Jamovi Project*; Jamovi: Sydney, Australia, 2022.
58. Lakens, D. Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Front. Psychol.* **2013**, *4*, 863. [CrossRef]
59. Rosenthal, J.A. Qualitative descriptors of strength of association and effect size. *J. Soc. Serv. Res.* **1996**, *21*, 37–59. [CrossRef]
60. Noguchi, K.; Gel, Y.R.; Brunner, E.; Konietschke, F. nparLD: An R software package for the nonparametric analysis of longitudinal data in factorial experiments. *J. Stat. Softw.* **2012**, *50*, 1–23. [CrossRef]
61. Vargha, A.; Delaney, H.D. A critique and improvement of the CL common language effect size statistics of McGraw and Wong. *J. Educ. Behav. Stat.* **2000**, *25*, 101–132.
62. Pan, C.-Y. The efficacy of an aquatic program on physical fitness and aquatic skills in children with and without autism spectrum disorders. *Res. Autism Spectr. Disord.* **2011**, *5*, 657–665. [CrossRef]
63. Fragala-Pinkham, M.A.; Haley, S.M.; O'neil, M.E. Group swimming and aquatic exercise programme for children with autism spectrum disorders: A pilot study. *Dev. Neurorehabil.* **2011**, *14*, 230–241. [CrossRef]
64. Kozlowski, K.F.; Lopata, C.; Donnelly, J.P.; Thomeer, M.L.; Rodgers, J.D.; Seymour, C. Feasibility and associated physical performance outcomes of a high-intensity exercise program for children with autism. *Res. Q Exerc. Sport.* **2021**, *92*, 289–300. [CrossRef]
65. Arslan, E.; Ince, G.; Akyüz, M. Effects of a 12-week structured circuit exercise program on physical fitness levels of children with autism spectrum condition and typically developing children. *Int. J. Dev. Disabil.* **2022**, *68*, 500–510. [CrossRef]
66. Jackson, S.L.J.; Abel, E.A.; Reimer, S.; McPartland, J.C. Brief Report: A Specialized Fitness Program for Individuals with Autism Spectrum Disorder Benefits Physical, Behavioral, and Emotional Outcomes. *J. Autism Dev. Disord.* **2022**, 1–9. [CrossRef]
67. Xu, C.; Yao, M.; Kang, M.; Duan, G.; Bocalini, D.S. Improving Physical Fitness of Children with Intellectual and Developmental Disabilities through an Adapted Rhythmic Gymnastics Program in China. *Biomed. Res. Int.* **2020**, *2020*, 2345607. [CrossRef]
68. Pitetti, K.H.; Rendoff, A.D.; Grover, T.; Beets, M.W. The efficacy of a 9-month treadmill walking program on the exercise capacity and weight reduction for adolescents with severe autism. *J. Autism Dev. Disord.* **2007**, *37*, 997–1006. [CrossRef] [PubMed]
69. García-Hermoso, A.; Ramírez-Vélez, R.; García-Alonso, Y.; Alonso-Martínez, A.M.; Izquierdo, M. Association of cardiorespiratory fitness levels during youth with health risk later in life: A systematic review and meta-analysis. *JAMA Pediatr.* **2020**, *174*, 952–960. [CrossRef]
70. Fukuda, D.H.; Stout, J.R.; Burris, P.M.; Fukuda, R.S. Judo for children and adolescents: Benefits of combat sports. *Strength Cond. J.* **2011**, *33*, 60–63. [CrossRef]
71. Gutierrez-Garcia, C.; Astrain, I.; Izquierdo, I.; Gomez-Alonso, M.T.; Yague, J.M. Effects of judo participation in children: A systematic review. *Ido Mov. Cult. J. Martial Arts Anthropol.* **2018**, *18*, 63–73.
72. Toskić, D.; Lilić, L.; Toskić, L. The influence of a year-long judo training program on the development of the motor skills of children. *Act. Phys. Educ. Sport* **2014**, *4*, 55–58.
73. Walaszek, R.; Sterkowicz, S.; Chwała, W.; Sterkowicz-Przybycień, K.; Walaszek, K.; Burdacki, M.; Klys, A. Assessment of the impact of regular judo practice on body posture, balance, and lower limbs mechanical output in six-year-old boys. *J. Sport Med. Phys. Fit.* **2017**, *57*, 1579–1589. [CrossRef] [PubMed]
74. Krstulović, S.; Maleš, B.; Žuvela, F.; Erceg, M.; Miletić, Đ. Judo, soccer and track-and-field differential effects on some anthropological characteristics in seven-year-old boys. *Kinesiology* **2010**, *42*, 56–64.
75. Sekulic, D.; Krstulovic, S.; Katic, R.; Ostojic, L. Judo training is more effective for fitness development than recreational sports for 7-year-old boys. *Pediatr. Exerc. Sci.* **2006**, *18*, 329–338. [CrossRef]
76. Brasil, I.; Monteiro, W.; Lima, T.; Seabra, A.; Farinatti, P. Effects of judo training upon body composition, autonomic function, and cardiorespiratory fitness in overweight or obese children aged 8-to 13 years. *J. Sports Sci.* **2020**, *38*, 2508–2516. [CrossRef] [PubMed]
77. Renziehausen, J.M.; Rivera, P.M.; Leahy, N.A.; Fukuda, D.H.; Garcia, J.M. The Feasibility of a Community-Based Judo Program and Cortisol Collection in Children with Autism. *Adv. Neurodev. Disord.* **2022**, *6*, 100–105. [CrossRef]

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Improving motor skills and psychosocial behaviors in children with autism spectrum disorder through an adapted judo program

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Introduction: This study aimed to investigate the long-term effects of an adapted judo program on the motor skills and psychosocial abilities of children with Autism Spectrum Disorder (ASD).

Methods: All participants had been diagnosed with ASD and were assessed twice, one time at the start of the intervention and again 6 months later, with the Test of Gross Motor Development (TGMD-3) and the Gilliam Autism Rating Scale-Third Edition (GARS-3). A one-way repeated measures MANOVA was carried out in order to evaluate these assessments, and a mediation analysis was done to determine the relationship between them.

Results: The experimental group significantly improved ($p < 0.05$) from the pre-test to the post-test for several subtests of the TGMD-3 and the GARS-3.

Conclusion: The study shows that participation in an adapted judo program clearly helps to improve the motor skills and psychosocial behaviors of children with ASD.

KEYWORDS

combat sports, ASD, TGMD, GARS, intellectual disabilities, adapted sports

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder with an unknown cause that manifests in difficulties and barriers associated with social communication and repetitive and stereotyped behaviors (American Psychiatric Association, 2013). There has been a recent increase in the prevalence of ASD among children, as in the mid-1990s it was thought to affect 11.6 out of 1,000 people in this age group (Baird et al., 2006), while more recent studies have put this figure as high as 18.5 per 1,000 (Maenner et al., 2020).

Several researchers have shown that people with ASD experience difficulties in social interactions and communication (Jones and Frederickson, 2010; Wilmshurst and Brue, 2018), leading to problems in their relationships with others. They are often characterized by a lack of motivation, resistance to change, and difficulties following social rules (Habib et al., 2018). Additionally, people with ASD often have problems with motor skills (Colombo-Dougovito and Block, 2019; Crucitti et al., 2020), affecting their ability to interact with others including successful social participation (Bodison, 2015).

It is yet unclear whether these motor difficulties are a direct consequence of the disorder itself or whether they emerge from an amalgam of other factors, such as a lack of opportunities to practice these abilities or a lack of motivation. It is clear, though, that children with ASD tend to lag behind their peers without the disorder when it comes to motor development (Pan et al., 2017; Sansi et al., 2021). This means that it is sometimes difficult for children with ASD to participate in activities that require motor skills that would otherwise be typical for their age groups, thereby further limiting their opportunities for social interaction.

Substantial evidence exists detailing these motor limitations. Studies have found that children with ASD perform poorly compared to their peers across various motor domains including balance, postural control and overall coordination (Downey and Rapport, 2012), gait disturbances, lateral movement and fine motor skills (Kaur et al., 2018). During early infancy, the differences in motor development between children with and without ASD are less pronounced. However, starting at about 18 months, the gap becomes more apparent, with children with ASD displaying less interest in play and spontaneous games (Serrada-Tejeda et al., 2021). This could further affect their motor and sensory development and, in turn, lead them to participate less in leisure and social activities throughout childhood.

The positive impact of physical exercise reducing ASD symptomology and the associated comorbidities has been sufficiently explored. Several systematic reviews and meta-analyses focused on synthesizing the effects of physical activity and sports participation in this population (Hume et al., 2021). Potential benefits noted in the literature include how physical activity can contribute to improvements in the social relations and communication skills of those with ASD (Bremer et al., 2016; Howells et al., 2019; Chan et al., 2021), how exercise can help reduce stereotyped behaviors (Ferreira et al., 2019), and the broad range of improvements in motor skills, social skills, and physical fitness resulting from these types of interventions (Sowa and Meulenbroek, 2012; Sam et al., 2015; Healy et al., 2018).

Participating in combat sports can help improve the physical and mental health of children with ASD, particularly when it comes to improving participants' motor skills (Kim et al., 2016; Sarabzadeh et al., 2019), but there are also studies evaluating the benefits in social terms. For example, researchers have shown that karate training can significantly reduce stereotyped behaviors and improve social interaction (Bahrami et al., 2012; Movahedi et al., 2013). It is worth highlighting that martial arts and combat sports training requires moderate-to-vigorous physical activity and, simultaneously, the need for concentration and self-control (Garcia et al., 2019). These sports may also appeal to young people with ASD because of the repetitive nature of the tasks involved in the training (Bell et al., 2016).

Among martial arts, the specific characteristics of judo, with its alternating phases of vigorous physical activity and low-intensity exercises focused on mindfulness, may provide an ideal method to reduce the stress response (e.g., cortisol levels) of young people with ASD (Renziehausen et al., 2022). Indeed, a recent systematic review (Pečnikar Oblak et al., 2020) highlights the health and psychosocial benefits that people with mental disabilities can gain from participating in adapted judo programs. Short-term judo programs have reduced repetitive behaviors and improved social communication, interaction, and emotional responsiveness (Morales et al., 2021). At the same time, a study with an eight-week intervention (Rivera et al., 2020) found a decrease in aggressive behaviors among children with ASD who had taken part in an adapted judo program. Other researchers have demonstrated the viability and effectiveness of these programs, observing that the participants tend to embrace and enjoy adapted judo and express a desire to continue participating (Tomey, 2017). Adapted judo programs have registered good adherence rates leading to overall increases in moderate-to-vigorous physical activity (Garcia et al., 2019). However, the impact of participation in extended-duration judo training beyond 8 weeks in children with ASD has yet to be fully explored.

In light of this evidence of the effectiveness of adapted judo programs for people with ASD, the main objective of this study is to determine the effects of a long-term adapted judo program on the motor skills and psychosocial behaviors in children with ASD. The secondary objective is to observe the relationship between motor skills and the severity of psychosocial behavior symptoms of children with ASD. The hypothesis is that the participants in the adapted judo program will improve the motor skills and psychosocial behaviors assessed in the study.

Materials and methods

Participants

This study featured the participation of 40 children with a mean age of 11.07 (±1.73) years, a mean height of 145.9 (±15.81) cm and a mean weight of 47.71 (±16.71) kg. A sample description by group is presented in Table 1. The participants were recruited with the

TABLE 1 Sample characteristics by group.

Variable	Experimental group ($n = 21$) Mean (standard deviation)	Control group ($n = 19$) Mean (standard deviation)
Age (years)	10.82 (±1.6)	11.35 (±1.9)
Height (cm)	143.91 (±13.01)	147.95 (±16.45)
Weight (kg)	45.96 (±17.09)	49.67 (±12.01)
IQ	60.8 (±3.05)	61.9 (±4.13)

assistance of several different associations of families of people with ASD and schools for children with special needs. All the participants had been diagnosed with ASD according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition (DSM-5). The psychological reports provided by the participants indicated that their intelligence quotients (IQ) ranged from 55 to 70 (mean value 61.4 ± 3.55). Exclusion criteria included individuals who had been advised not to participate in physical exercise, those who had previously taken judo lessons and those who were already participating in extracurricular athletic activities. Participation was voluntary, and the participants and their families were verbally and in writing informed of the program's characteristics. The participant's parents, legal guardians, and children signed an informed consent document explaining the program's plan and objectives. All the protocols within this research, including the treatment of the participant's personal information, followed the 1975 Declaration of Helsinki requirements and the subsequent revisions. This study received the approval of the Research Ethics Committee of Universitat Ramon Llull under file number CER URL_2019_2020_003, and the trial was registered on Clinicaltrials.gov (NCT04523805).

Procedure

The present study was prospective and employed a convenience sampling method. The sample was divided into two groups according to their willingness and commitment to participate in an adapted judo program over a school year. Thus, the sample consisted of an experimental group ($n = 21$) that took part in a 6-month adapted judo program and a control group ($n = 19$) that did not participate in extracurricular sports over this period. The experimental group participated exclusively in the adapted judo program without the possibility of regular participation in other sports activities, which could bias the results. Each participant was assessed twice, at the beginning and the end of the program, under stable conditions and in the same room where the judo sessions were held.

Intervention

The experimental group took part in a 6-month adapted judo program. The judo sessions were performed in a large, well-ventilated, and safe space suitable for judo practice. The judo mat had a surface area of 120 m^2 and was made of high-density foam designed to reduce the impact of falls, ensuring safe practice. Each participant was outfitted with a *judogi* (the judo suit consisting of a cotton jacket, trousers, and a belt).

Participants completed one session per week of 90 min of duration. Two judo teachers with 7th and 6th degree black belts, with academic backgrounds in pedagogy and sports sciences, respectively, led the sessions, and at least four volunteer judo instructors lent support. The sessions consisted of judo-specific tasks preceded by a warm-up and ending with a cool-down. As previously employed in other studies of our research group (Morales et al., 2021), the judo-specific content of the sessions included:

- Different types of general movements and falling techniques (from stepping in all directions to body repositioning and turning, movements from stable to unstable supports).
- Simplified judo-specific movements and games (building up body contact through games, primary focus on essential/simplified judo movements).
- Body control techniques on the ground and throws (progression of techniques from simplified to more complex movements).
- Repetitions of basic technical movements in different directions (pulling, pushing, holding, lifting).

The method of instruction utilized the principle of gradual progression, ensuring the consolidation of concepts learned in the initial lessons before moving on to more complex activities and material. Each participant progressed at his or her own pace.

The judo program was adapted by applying the principle: "normal where possible, adapted where necessary" (Morales et al., 2022). The main attributes of our adapted judo program were:

- The learning method chosen was imitation. The instructor presented techniques and then guided the practice.
- The employment of very marked routines based on brief and clear instructions in the form of the five "W" (who, when, what, where, why).
- Judo teachers spoke in a calm and firm voice. They gave objective instructions and refrained from using figurative language or irony.
- It can be deduced that sometimes it can be difficult for people with ASD to see the big picture because they perceive so many details.
- Instructors were trained to keep calm and not criticize the slowness of reproducing movements that sometimes characterize people with ASD.
- Spontaneous and unexpected behavior changes were monitored and redirected by judo teachers. They were aware that each participant required their own time.
- Instructions were given repetitively and employed a broad spectrum of senses, not only verbal cues. The isolated use of sensory instructions, one at a time, can support perception. For example, the instructor may physically demonstrate with verbal instructions and once without speaking.

Assessment instruments

All participants completed two assessment sessions, once at the start of the intervention and again 6 months later, with the Gilliam

Autism Rating Scale-Third Edition (GARS-3; Gilliam, 2014) and the Test of Gross Motor Development (TGMD-3; Ulrich, 2019).

The TGMD-3 is an instrument designed to assess the gross motor performance of children from 3 to 10 years of age. The assessment includes subscales measuring Locomotor Skills and Ball Skills, representing the fundamental motor skills most commonly taught in physical education classes worldwide. This study used a visual support protocol previously validated for children with ASD (Allen et al., 2017), whereby the instructors explained the test elements *via* a combination of illustrated cards, verbal instructions and physical demonstrations.

In addition to detecting delays and limitations in children's gross motor skill development, the TGMD-3 can also be used as a research tool to explore gross motor skills, both among children with a typical development pattern and among those with atypical movement functioning (Ulrich, 2019). The Locomotor Skills subscale features six movements that require coordination and movements in various directions (Run, Gallop, Hop, Skip, Horizontal jump, Slide). The Ball Skills subscale assesses throwing, hitting and catching skills through seven tasks: Two-hand strike, One-hand strike, Dribble, Two-hand catch, Kick, Overhand throw, and Underhand throw. The test is video recorded and later analyzed by trained independent (blinded) raters using a screening tool and the criteria set out in the TGMD-3 for each task. Participants are assigned a score of "1" for each task they successfully completed and a score of "0" when they do not meet the criteria. After this analysis, the locomotor and ball skills subscale scores are summed, yielding a raw total TGMD-3 score.

The GARS-3 is an instrument used to assess changes in the severity of ASD behaviors. As described in a previous work of our research group (Morales et al., 2021), the GARS-3 includes 56 items describing characteristic behaviors of individuals with ASD. The items are grouped into six subscales: repetitive behaviors (RB), social interaction (SI), social communication (SC), emotional responses (ER), cognitive style (CS), and maladaptive speech (MS). Parents and caregivers had to score each item on a four-point Likert-type scale (0 = never observed; to 3 = frequently observed) spending approximately from 5 to 10 min, and based on the frequency of occurrence of each item under ordinary circumstances in a 6-h period. The raw scores for each subscale were summed, yielding a total GARS-3 score. Both the pre-and post-tests were carried out using pen and paper. Parents and caregivers had the opportunity to ask questions about item interpretation.

Statistical analysis

All descriptive data from the dependent variables are presented with the mean ± standard deviation (SD). The normality of the distribution of each variable was checked with a Shapiro-Wilks test. A one-way repeated measures MANOVA evaluated the effects of an intra-subject factor (TIME: pre-post) and an inter-subject factor (GROUP: control-experimental) of each dependent variable.

Multivariate contrast monitoring was performed using univariate contrast to determine any significant differences in dependent variables between conditions. The effect size of the multivariate and univariate contrasts was calculated using the partial eta squared (η^2p) and interpreted as a small, medium, or large effect when the values of η^2p reached 0.0099, 0.0588, and 0.1379, respectively (Cohen, 1988). When univariate contrasts showed statistically significant interaction effects, pairwise comparisons with Bonferroni correction were applied.

A simple mediation analysis model measured the relationship between motor skills and the severity of psychosocial behaviors among children with ASD. This simple mediation analysis examined motor skills' direct and indirect effects using the total TGMD-3 post-test scores as a predictive variable (PV) of the total GARS-3 post-test scores, representing the dependent variable (DV) of psychosocial behaviors. This analysis used the variation in the total GARS-3 score (calculated as the difference between the pre-and post-test scores) as a mediating variable (MV). The associations explored in this model are represented in Figure 1.

A simple mediation analysis indicates a direct effect (c) when the PV exerts an influence on the DV without taking into account the analysis of the participation of the MV. Meanwhile, the model indicates an indirect effect (a and b) when the PV exerts its influence on the DV through the MV. Finally, a total effect is registered when the PV influences the DV in the presence of the MV but not *via* this mediating variable.

All the statistical analyses were calculated using the Statistical Package for Social Science version 24.0 software (SPSS, Inc., Chicago, IL, United States). A significance level of $p < 0.05$ was used for all tests. (Data available at https://doi.org/10.6084/m9.figshare.20465337).

Results

All the dependent variables did not show significant differences at the pre-test between the control and experimental groups, indicating that they were homogeneous groups at the beginning of the intervention.

The multivariate analysis applied to the outputs of the TMGD-3 test showed a significant time × group interaction ($F_{3,43} = 10.18$, $p < 0.001$, $\eta^2p = 0.41$) and a significant effect of time ($F_{3,43} = 23.08$, $p < 0.001$, $\eta^2p = 0.61$). Follow-up of the univariate analysis in this test showed an interaction effect (time × group) in the Locomotor Skills subscale score ($F_{1,42} = 27.87$, $p < 0.001$, $\eta^2p = 0.38$) and the total TGMD-3 score ($F_{1,42} = 20.06$, $p < 0.001$, $\eta^2p = 0.31$). The Ball Skills subscale did not show interaction effect. Finally, we observed significant improvements in the experimental group between the pre-and post-test in the Locomotor Skills subscale ($p < 0.001$) and Total TGMD-3 ($p < 0.001$) (Figure 2).

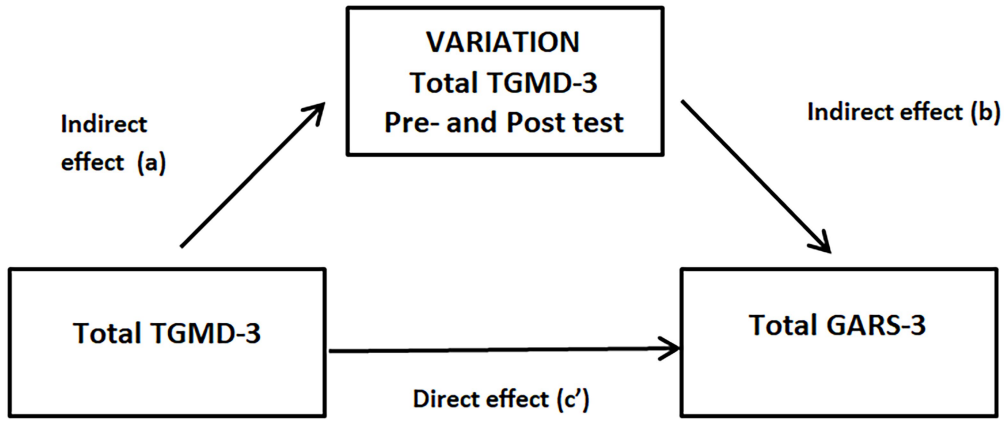

FIGURE 1
Mediation analysis. Contribution of total TGMD-3 post-test scores on total GARS-3 post-test scores through the variation in the total GARS-3 score (calculated as the difference between the pre-and post-test scores). TGMD-3=Test of Gross Motor Development-Third Edition; GARS-3=Gilliam Autism Rating Scale-Third Edition.

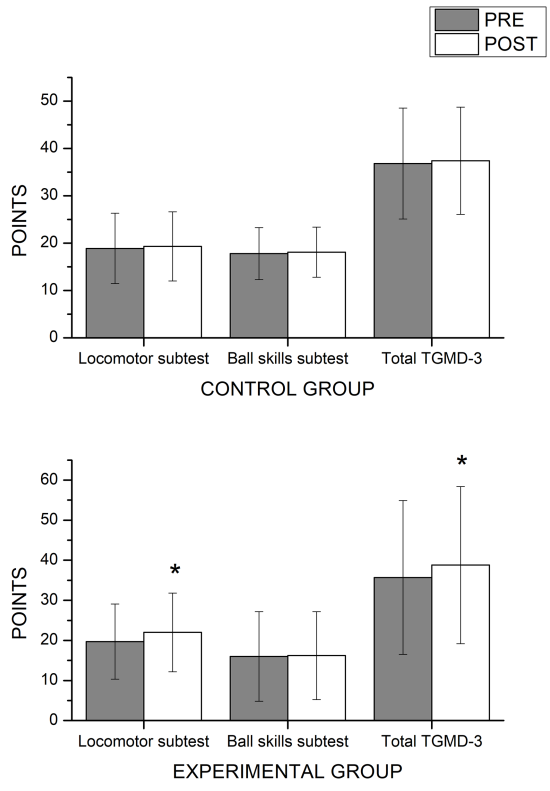

FIGURE 2
Pre- and post-scores in Total TGMD-3 and its Locomotor and Ball Skills subscales after 6 months adapted judo program by group. *Significant differences ($p < 0.05$).

The multivariate analysis applied to the outputs of the GARS-3 test showed a significant time × group interaction between ($F_{7,32} = 31.25$, $p < 0.001$, $\eta^2 p = 0.87$) and a significant effect of time ($F_{7,32} = 12.06$, $p < 0.001$, $\eta^2 p = 0.72$). Follow-up of the univariate analysis in this test showed an interaction effect (time × group) in the RB subscale score ($F_{1,38} = 6.29$, $p < 0.016$, $\eta^2 p = 0.14$), SI subscale score ($F_{1,38} = 60.39$, $p < 0.001$, $\eta^2 p = 0.61$), ER subscale score ($F_{1,38} = 8.40$, $p < 0.006$, $\eta^2 p = 0.18$), CS subscale score ($F_{1,38} = 4.20$, $p < 0.046$, $\eta^2 p = 0.10$) and the total GARS-3 score ($F_{1,38} = 17.39$, $p < 0.001$, $\eta^2 p = 0.31$). The SC and MS subscales did not show interaction effect. Finally, the pairwise comparison showed significant improvements in the experimental group between the pre and post-test in the RB ($p = 0.01$), SI ($p < 0,001$), ER ($p = 0.002$) and CS ($p = 0.005$) subscales, and Total GARS-3 ($p < 0.001$). (Figure 3).

The results of the simple mediation analysis (Table 2) showed a significant total effect when the PV (total TMGD-3 score) influences the DV (total GARS-3 score) in the presence of the MV (GARS-3 variation), but not through the latter variable. This result demonstrates that motor skills performance is closely linked to the severity of ASD in terms of psychosocial behaviors and that the variation in motor skills recorded during the intervention influenced this relationship, albeit a small one, because the values for the variation include the control group.

Discussion

This study offers a complete description of the effects of a long-term adapted judo program on children with ASD and illustrates the psychosocial behavioral changes that occurred in the sample during the intervention.

The study's results confirm the initial hypothesis, as most indicators showed improvements in the experimental group's scores after participating in the adapted judo program. After the intervention, the children in the experimental group recorded improvements in motor skills, as measured by the total score on the TGMD-3 and the Locomotor Skills subscale. Meanwhile, the children in the control group did not display any significant changes. The experimental group also showed significant improvements in the total GARS-3 score and on the subscales measuring RB, SI, ER, and CS.

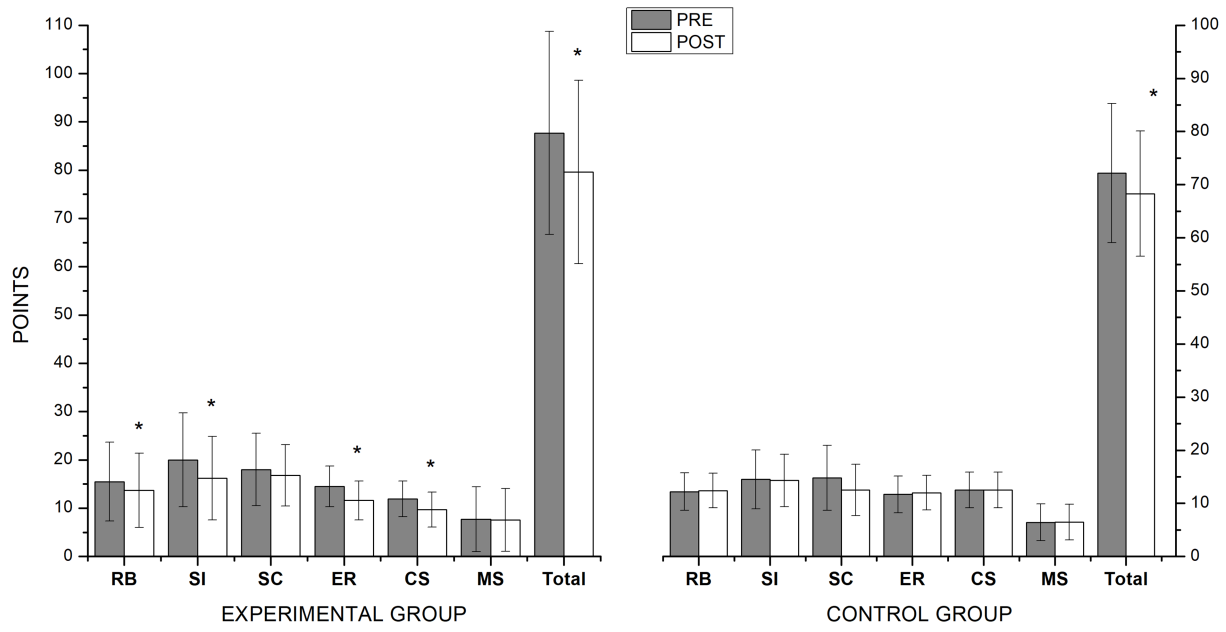

FIGURE 3
Pre- and post-scores on the Gilliam Autism Rating Scale-Third Edition (GARS-3) subscales forrepetitive behaviors (RB), social interaction (SI), social communication (SC), emotional responses (ER), cognitive style (CS), and maladaptive speech (MS) after 6 months of adapted judo program intervention. *Significant differences ($p < 0.05$).

TABLE 2 The approximate mediating role of the variation of motor skills in the relationship between psychosocial behaviors and motor skills.

Effect	Coefficient	95% Confidence interval	Z	p-value	% mediation
Indirect (a × b)	0.009	−0.01; 0.02	1.00	0.316	3.76
Direct (c)	0.243	−0.34; −0.14	4.64	<0.001*	96.24
Total (c + a × b)	0.234	−0.33; −0.13	4.32	<0.001*	100.0

*$p < 0.05$ indicates statistically significant differences.

It has been established that children with ASD tend to engage in sedentary activities and generally are less physically active than their neurotypical peers during their free time (Zhao and Chen, 2018). As such, guided activities like the judo sessions described within this study might be needed to encourage the participation of children with ASD in physical activity. In fact, some prior studies of short-term adapted judo programs for children with this disorder have achieved high adherence among participants, increased moderate-to-vigorous physical exercise (Garcia et al., 2019), and improved satisfaction and self-confidence (Tomey, 2017).

We have been unable to find other studies that have examined the improvement of the motor skills of children with ASD through judo. There are, however, some examples of research using other martial arts disciplines or other combat sports, such as a case study observing the balance and postural control benefits of an intervention program based on aikido (Polak et al., 2019) and another eight-week intervention using taekwondo (Kim et al., 2016). Systematic participation in judo requires balance and coordination tasks as well as the development of grip strength (Demiral, 2011). In addition to the usual elements of judo, the adapted program that was applied in this study included a large number of judo-specific movement exercises that coincided with the tasks assessed on the Locomotor Skills subscale of the TGMD-3, meaning that it was reasonable to expect the improvements that were achieved in this regard. Meanwhile, there is evidence that participation in judo can also help improve motor skills such as agility, coordination and balance among neurotypical children (Protic-Gava et al., 2019; Purnamasari et al., 2021). Another study featuring a year-long judo program in children found improvements in various domains of motor skills and physical fitness, such as hand strength, flexibility and overall coordination (Toskić et al., 2014), while judo training has been shown to improve body posture, balance and lower limb muscle strength (Walaszek et al., 2017).

Meanwhile, Lo et al. (2019) have shown that using judo in school can improve spatial orientation skills. These researchers recommended using judo with people with ASD in order to improve their executive functioning. Our results echo these findings, as the participants showed improvements in postural control and spatio-temporal orientation (Run, Gallop, Hop, Skip, Horizontal jump, Slide) following the intervention. Additionally, a high degree of correlation was found between motor skills and executive functioning, suggesting a relationship between these two constructs and those interventions aimed at one of these two areas might also impact the other (Hilton et al., 2014). In light of

this relationship between motor skills and executive functioning, improvements in the former might help children with ASD in their everyday activities and, in broader terms, contribute to increasing their quality of life.

After participating in the long-term adapted judo program, the children with ASD significantly reduced psychosocial behavioral ratings. The results are similar to those found in our previous work following an eight-week intervention (Morales et al., 2021). In both cases, significant improvements were recorded on six of the subscales of the GARS-3, although the list of scales with significant differences was not the same in the two studies. There were no significant differences in the subscale measuring maladaptive speech in either of the studies, which might indicate that participating in sports does not tend to improve the language skills of people with ASD, as previously reported following an intervention involving horseback riding (Gabriels et al., 2015). Compared to the earlier short-term judo intervention, one unique finding of the current study is that the Communication subscale did not display significant improvements. This result stands in contrast with the general trend reported in systematic reviews and meta-analyses of physical activity and sports participation interventions (Bremer et al., 2016; Healy et al., 2018; Howells et al., 2019), which have observed improvements in communication skills presumably due to the experiences of teamwork and social interaction.

The overall results regarding psychosocial behaviors coincide with previous investigations following short-term adapted judo programs, which have been found to decrease stress, increase satisfaction with the activity, and improvements in social relations (Rivera et al., 2020; Renziehausen et al., 2022). These findings are further confirmed by other experiences with neurotypical people that have found that participating in judo increases empathy, reduces aggressive behavior (Ennigkeit and Beek, 2019) and contributes to the development of self-discipline, serenity, efficient problem solving and socio-moral sensitivity (Sterkowicz-Przybycień et al., 2014). It is also worth highlighting the successful record of adaptations of other martial arts in reducing stereotyped behaviors and improving social interactions within this population (Bahrami et al., 2012; Movahedi et al., 2013; Phung and Goldberg, 2019). Combat sports and martial arts like judo have clear structures and other elements that make them very suitable for people with ASD and are likely to contribute to improvements in various aspects of their everyday lives. These kinds of sports can be adapted to the individual characteristics of each participant and can be applied in different contexts, such as various exercise intensities that might cater to children with ASD. Additionally, these sports are highly structured and involve repetitive movements that are easily mimicked and mental imagery with opponents (Bahrami et al., 2012). One possible reason for the effectiveness of the adapted judo program was that it was designed according to some of the traditional tenets of martial arts training. In other words, it extended beyond physical activity, with additional emphases on self-discipline and behavioral, emotional and cognitive control, as previously recommended for combat sports and martial arts interventions for children with ASD (Morales et al., 2021).

Concerning the secondary objective of this study, the results showed a significant relationship between the variables measuring motor skills and those measuring psychosocial behaviors. The participants' total TGMD-3 scores directly affected the total GARS-3 score, with the mediation calculated at 96.24%. The same mediation analysis also showed a significant total effect, as determined by the mediation effect calculated by adding the direct effect and the indirect effect represented by the variation in scores on the TGMD-3 during the intervention period. These results suggest that motor skills and psychosocial behaviors are closely linked and that interventions addressing motor skills may influence this relationship to an extent.

There is considerable evidence showing that children with ASD experience greater difficulties with motor development than their peers (Miyahara, 2013). MacDonald et al. (2014) found a correlation between gross and fine motor skills and the severity of ASD. Specifically, they observed that more severe cases of ASD were associated with poorer fine and gross motor skills. Beyond delays in motor development among children with ASD, researchers have found links between these motor problems and the development of language and cognitive abilities (Bedford et al., 2016) and adaptive conduct (MacDonald et al., 2013), as well as between motor development and social skills (MacDonald et al., 2013).

One question that regularly emerges within the scientific literature on this topic is whether motor difficulties should be viewed as a central characteristic of ASD and whether this disorder should be co-diagnosed along with Developmental Coordination Disorder (DCD; Camden et al., 2022). Sumner et al. (2016) examined the relationship between motor skills and social abilities in a group of people with ASD, another with DCD and a control group in children, finding a good deal of overlap between the assessments of the motor and social skills of the ASD and DCD groups, both of which recorded lower scores than the control. Additionally, motor skills were found to predict social functioning in both of these groups.

Fundamental motor skills are the building blocks in developing more complex gross motor movements. If the intervention described here successfully improved motor skills, then the participants should be inspired to take a more positive view of their own motor abilities. This, in turn, might encourage them to continue participating in judo, as has been the case with other judo programs for people with ASD (Tomey, 2017; Garcia et al., 2019). Judo programs could also positively affect their social functioning and physical health. Importantly, it could also help them develop the motor skills needed to participate in other sports and physical activity programs with their neurotypical peers (Colombo-Dougovito and Block, 2019).

In childhood, free play is an opportunity to develop a range of motor skills. There does not seem to be any reason why children with ASD should not participate in play as neurotypical children do, but starting at the age of two the former tend to reduce their

free play interactions (Serrada-Tejeda et al., 2021). However, they continue to display interest in directed play. In addition to offering directed activities, it is important to strive to adopt an inclusive approach to increase their effectiveness in physical activity interventions (Sansi et al., 2021). This could help address the difficulties that people with ASD often have in finding activities that meet their needs. Some of the motor development problems experienced by children with ASD might be due to this lack of opportunity. Adapted sports programs like the one described here are useful because they are designed specifically for the enjoyment of children with ASD and offer them the chance to contact other children. The characteristics of judo training mean that there is a combination of peer learning, which helps improve the relationships among the students with ASD, and guided activities where they learn the technique of the sport by imitating their instructors. Finally, the structure of judo sessions and the routines associated with the sport, such as formal procedures, including bowing, might help the participants overcome some of the difficulties they face in their everyday lives and at school.

This study may have some limitations because the data was collected from non-blinded caregivers, which was the case for the GARS-3. This can be a source of confusion in this type of intervention-based research, as it can be unclear whether the knowledge of the intervention by the caregivers could influence their answers or whether the results could be affected by subjective factors such as the expectations involved with the adapted judo program. In any case, the GARS-3 protocol recommends that the people most familiar with the participants' behavior complete the questionnaire. Furthermore, the sampling distribution within groups was not randomized. As stated in the methods section, they were distributed into two groups according to their willingness and commitment to participate in an adapted judo program over a school year. The lack of randomization could have biased the results; nevertheless, experimental and control groups presented similar values in all the dependent variables at the pre-test, indicating that they were homogeneous groups at the beginning of the intervention.

Conclusion

The most important conclusions of this study are that participating in a 6-months adapted judo program improved the motor skills and psychosocial behaviors of children with ASD. We can also conclude that there is a close relationship between motor skills and psychosocial behaviors, as the children with greater severity of autism-related behaviors were likely to display poorer motor skills. Meanwhile, the adaptation of the judo program increases its efficiency and could help participants adapt better to their everyday lives and improve their quality of life. In the present work, we have presented judo-specific content and instructional cues that could help apply the judo program to young people with ASD. Future research is warranted to study the effects of adapted judo programs in adults with ASD or other intellectual disabilities.

Data availability statement

The original contributions presented in the study are publicly available. This data can be found at: https://doi.org/10.6084/m9.figshare.20465337.

Ethics statement

The studies involving human participants were reviewed and approved by the Research Ethics Committee of Universitat Ramon Llull under file number CER URL_2019_2020_003, and the trial was registered on Clinicaltrials.gov (NCT04523805). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

JM and EC conceptualized the study, analyzed the data, and wrote the manuscript. EP assisted with conceptualizing the study, writing, and editing the manuscript. DHF assisted with data collection and editing the manuscript. VG assisted with data collection, writing, and editing the manuscript. MG-B assisted with data collection, interpretation of the results, writing, and editing the manuscript. MS-S assisted with interpretation of the results, writing, and editing the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Allen, K. A., Bredero, B., Van Damme, T., Ulrich, D. A., and Simons, J. (2017). Test of gross motor development-3 (TGMD-3) with the use of visual supports for children with autism spectrum disorder: validity and reliability. *J. Autism Dev. Disord.* 47, 813–833. doi: 10.1007/s10803-016-3005-0

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders: DSM-5. 5th Edn*. Arlington, VA: American Psychiatric Association.

Bahrami, F., Movahedi, A., Marandi, S. M., and Abedi, A. (2012). Kata techniques training consistently decreases stereotypy in children with autism spectrum disorder. *Res. Dev. Disabil.* 33, 1183–1193. doi: 10.1016/j.ridd.2012.01.018

Baird, G., Simonoff, E., Pickles, A., Chandler, S., Loucas, T., Meldrum, D., et al. (2006). Prevalence of disorders of the autism spectrum in a population cohort of children in South Thames: the special needs and autism project (SNAP). *Lancet* 368, 210–215. doi: 10.1016/S0140-6736(06)69041-7

Bedford, R., Pickles, A., and Lord, C. (2016). Early gross motor skills predict the subsequent development of language in children with autism spectrum disorder. *Autism Res.* 9, 993–1001. doi: 10.1002/aur.1587

Bell, A., Palace, K., Allen, M., and Nelson, R. (2016). Using martial arts to address social and behavioral functioning in children and adolescents with autism spectrum disorder. *Ther. Recreat. J.* 50, 176–181. doi: 10.18666/TRJ-2016-V50-I2-7287

Bodison, S. C. (2015). Developmental dyspraxia and the play skills of children with autism. *Am. J. Occup. Ther.* 69:6905185060. doi: 10.5014/ajot.2015.017954

Bremer, E., Crozier, M., and Lloyd, M. (2016). A systematic review of the behavioural outcomes following exercise interventions for children and youth with autism spectrum disorder. *Autism* 20, 899–915. doi: 10.1177/1362361315616002

Camden, C., Hérault, E., Fallon, F., and Couture, M. (2022). Children with autism and potential developmental coordination disorder: results from a literature review to inform the diagnosis process. *Curr. Dev. Disord. Rep.* 9, 1–8. doi: 10.1007/s40474-021-00242-0

Chan, J. S. Y., Deng, K., and Yan, J. H. (2021). The effectiveness of physical activity interventions on communication and social functioning in autistic children and adolescents: a meta-analysis of controlled trials. *Autism* 25, 874–886. doi: 10.1177/1362361320977645

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences. 2nd Edn*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Colombo-Dougovito, A. M., and Block, M. E. (2019). Fundamental motor skill interventions for children and adolescents on the autism spectrum: a literature review. *Rev J Autism Dev Disord.* 6, 159–171. doi: 10.1007/s40489-019-00161-2

Crucitti, J., Hyde, C., and Stokes, M. A. (2020). Hammering that nail: varied praxis motor skills in younger autistic children. *J. Autism Dev. Disord.* 50, 3253–3262. doi: 10.1007/s10803-019-04136-4

Demiral, S. (2011). The study of the effects of educational judo practices on motor abilities of 7-12 years aged judo performing children. *Asian Soc. Sci.* 7, 212–219. doi: 10.5539/ass.v7n9p212

Downey, R., and Rapport, M. J. K. (2012). Motor activity in children with autism: a review of current literature. *Pediatr. Phys. Ther.* 24, 2–20. doi: 10.1097/PEP.0b013e31823db95f

Ennigkeit, F., and Beek, F. L. (2019). The effect of judo on social behavior with special consideration of periods of reflection. *J. Martial Arts Res.* 2:7. doi: 10.15495/ojs_25678221_22_100

Ferreira, J. P., Ghiarone, T., Cabral Júnior, C. R., Furtado, G. E., Moreira Carvalho, H., Machado-Rodrigues, A. M., et al. (2019). Effects of physical exercise on the stereotyped behavior of children with autism spectrum disorders. *Medicina* 55:685. doi: 10.3390/medicina55100685

Gabriels, R. L., Pan, Z., Dechant, B., Agnew, J. A., Brim, N., and Mesibov, G. (2015). Randomized controlled trial of therapeutic horseback riding in children and adolescents with autism spectrum disorder. *J. Am. Acad. Child Adolesc. Psychiatry* 54, 541–549. doi: 10.1016/j.jaac.2015.04.007

Garcia, J. M., Leahy, N., Rivera, P., Renziehausen, J., Samuels, J., Fukuda, D. H., et al. (2019). Brief report: preliminary efficacy of a judo program to promote participation in physical activity in youth with autism spectrum disorder. *J. Autism Dev. Disord.* 50, 1418–1424. doi: 10.1007/s10803-019-04338-w

Gilliam, JE. (2014). *GARS-3: Gilliam Autism Rating Scale–Third Edition*. Austin, TX: Pro-Ed, Inc.

Habib, K., Montreuil, T., and Bertone, A. (2018). Social learning through structured exercise for students with autism spectrum disorders. *Rev. J. Autism Dev. Disord.* 5, 285–293. doi: 10.1007/s40489-018-0139-3

Healy, S., Nacario, A., Braithwaite, R. E., and Hopper, C. (2018). The effect of physical activity interventions on youth with autism spectrum disorder: a meta-analysis. *Autism Res.* 11, 818–833. doi: 10.1002/aur.1955

Hilton, C. L., Cumpata, K., Klohr, C., Gaetke, S., Artner, A., Johnson, H., et al. (2014). Effects of exergaming on executive function and motor skills in children with autism spectrum disorder: a pilot study. *Am. J. Occup. Ther.* 68, 57–65. doi: 10.5014/ajot.2014.008664

Howells, K., Sivaratnam, C., May, T., Lindor, E., McGillivray, J., and Rinehart, N. (2019). Efficacy of group-based organised physical activity participation for social outcomes in children with autism spectrum disorder: a systematic review and meta-analysis. *J. Autism Dev. Disord.* 49, 3290–3308. doi: 10.1007/s10803-019-04050-9

Hume, K., Steinbrenner, J. R., Odom, S. L., Morin, K. L., Nowell, S. W., Tomaszewski, B., et al. (2021). Evidence-based practices for children, youth, and young adults with autism: third generation review. *J. Autism Dev. Disord.* 51, 4013–4032. doi: 10.1007/s10803-020-04844-2

Jones, A. P., and Frederickson, N. (2010). Multi-informant predictors of social inclusion for students with autism spectrum disorders attending mainstream school. *J. Autism Dev. Disord.* 40, 1094–1103. doi: 10.1007/s10803-010-0957-3

Kaur, M., Srinivasan, S. M., and Bhat, A. N. (2018). Comparing motor performance, praxis, coordination, and interpersonal synchrony between children with and without autism spectrum disorder (ASD). *Res. Dev. Disabil.* 72, 79–95. doi: 10.1016/j.ridd.2017.10.025

Kim, Y., Todd, T., Fujii, T., Lim, J. C., Vrongistinos, K., and Jung, T. (2016). Effects of taekwondo intervention on balance in children with autism spectrum disorder. *J. Exerc. Rehabil.* 12, 314–319. doi: 10.12965/jer.1632634.317

Lo, W. L. A., Liang, Z., Li, W., Luo, S., Zou, Z., Chen, S., et al. (2019). The effect of judo training on set-shifting in school children. *Biomed. Res. Int.* 2019:8. doi: 10.1155/2019/2572016

MacDonald, M., Lord, C., and Ulrich, D. (2013). The relationship of motor skills and adaptive behavior skills in young children with autism spectrum disorders. *Res. Autism Spectr. Disord.* 7, 1383–1390. doi: 10.1016/j.rasd.2013.07.020

MacDonald, M., Lord, C., and Ulrich, D. A. (2014). Motor skills and calibrated autism severity in young children with autism spectrum disorder. *Adapt. Phys. Act. Q.* 31, 95–105. doi: 10.1123/apaq.2013-0068

Maenner, M. J., Shaw, K. A., and Baio, J. (2020). Prevalence of autism spectrum disorder among children aged 8 years—autism and developmental disabilities monitoring network, 11 sites, United States, 2016. *MMWR Surveill. Summ.* 69, 1–12. doi: 10.15585/mmwr.ss6904a1

Miyahara, M. (2013). Meta review of systematic and meta analytic reviews on movement differences, effect of movement based interventions, and the underlying neural mechanisms in autism spectrum disorder. *Front. Integr. Neurosci.* 7:16. doi: 10.3389/fnint.2013.00016

Morales, J., Fukuda, D. H., Garcia, V., Pierantozzi, E., Curto, C., Martínez-Ferrer, J. O., et al. (2021). Behavioural improvements in children with autism spectrum disorder after participation in an adapted judo programme

followed by deleterious effects during the COVID-19 lockdown. *Int. J. Environ. Res. Public Health* 18:8515. doi: 10.3390/ijerph18168515

Morales, J, Mulroy, J, Mulroy, T, Davitt, S, Desopo, L, Marcolini, C., et al. (2022). Adaptative judo best practice: autjudo. A handbook on how to teach judo to people with austistic spectrum disorder. Available at: https://www.recercat.cat/handle/2072/522713 (Accessed October 28, 2022).

Movahedi, A., Bahrami, F., Marandi, S. M., and Abedi, A. (2013). Improvement in social dysfunction of children with autism spectrum disorder following long term Kata techniques training. *Res. Autism Spectr. Disord.* 7, 1054–1061. doi: 10.1016/j.rasd.2013.04.012

Pan, C. Y., Chu, C. H., Tsai, C. L., Sung, M. C., Huang, C. Y., and Ma, W. Y. (2017). The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. *Autism* 21, 190–202. doi: 10.1177/1362361316633562

Pečnikar Oblak, V., Karpljuk, D., Vodičar, J., and Simenko, J. (2020). Inclusion of people with intellectual disabilities in judo: a systematic review of literature. *Archiv. Budo* 16, 245–260.

Phung, J. N., and Goldberg, W. A. (2019). Promoting executive functioning in children with autism spectrum disorder through mixed martial arts training. *J. Autism Dev. Disord.* 49, 3669–3684. doi: 10.1007/s10803-019-04072-3

Polak, E., Sikora, J., and Rachwał, M. (2019). An aikido-based intervention supporting the therapy of a child with autism spectrum disorders–a case study. *Ido Mov. Cult. J. Martial Arts Anthropol.* 19, 67–76. doi: 10.14589/ido.19.1S.11

Protic-Gava, B., Drid, P., and Krkeljas, Z. (2019). Effects of judo participation on anthropometric characteristics, motor abilities, and posture in young judo athletes. *Hum. Mov.* 20, 10–15. doi: 10.5114/hm.2019.83992

Purnamasari, I., Febrianty, M. F., and Novian, G. (2021). The effect of Tachiwaza on motor ability improvement in judo. *Act. J. Phys. Educ. Sport Health. Recreat.* 10, 131–135. doi: 10.15294/active.v10i3.51586

Renziehausen, J. M., Rivera, P. M., Leahy, N. A., Fukuda, D. H., and Garcia, J. M. (2022). The feasibility of a community-based judo program and cortisol collection in children with autism. *Adv. Neurodev. Disord.* 6, 100–105. doi: 10.1007/s41252-022-00237-x

Rivera, P., Renziehausen, J., and Garcia, J. M. (2020). Effects of an 8-week judo program on behaviors in children with autism spectrum disorder: a mixed-methods approach. *Child Psychiatry Hum. Dev.* 51, 734–741. doi: 10.1007/s10578-020-00994-7

Sam, K. L., Chow, B. C., and Tong, K. K. (2015). Effectiveness of exercise-based interventions for children with autism: a systematic review and meta-analysis. *Int. J. Learn. Teach.* 1, 98–103. doi: 10.18178/ijlt.1.2.98-103

Sansi, A., Nalbant, S., and Ozer, D. (2021). Effects of an inclusive physical activity program on the motor skills, social skills and attitudes of students with and without autism spectrum disorder. *J. Autism Dev. Disord.* 51, 2254–2270. doi: 10.1007/s10803-020-04693-z

Sarabzadeh, M., Azari, B. B., and Helalizadeh, M. (2019). The effect of six weeks of tai chi Chuan training on the motor skills of children with autism spectrum disorder. *J. Bodyw. Mov. Ther.* 23, 284–290. doi: 10.1016/j.jbmt.2019.01.007

Serrada-Tejeda, S., Santos-del-Riego, S., May-Benson, T. A., and Pérez-de-Heredia-Torres, M. (2021). Influence of ideational praxis on the development of play and adaptive behavior of children with autism spectrum disorder: a comparative analysis. *Int. J. Environ. Res. Public Health* 18:5704. doi: 10.3390/ijerph18115704

Sowa, M., and Meulenbroek, R. (2012). Effects of physical exercise on autism spectrum disorders: a meta-analysis. *Res. Autism Spectr. Disord.* 6, 46–57. doi: 10.1016/j.rasd.2011.09.001

Sterkowicz-Przybycień, K., Kłys, A., and Almansba, R. (2014). Educational judo benefits on the preschool children's behaviour. *J. Combat Sports Martial Arts* 5, 23–26. doi: 10.5604/20815735.1127449

Sumner, E., Leonard, H. C., and Hill, E. L. (2016). Overlapping phenotypes in autism spectrum disorder and developmental coordination disorder: a cross-syndrome comparison of motor and social skills. *J. Autism Dev. Disord.* 46, 2609–2620. doi: 10.1007/s10803-016-2794-5

Tomey, K. L. (2017). Effects of a modified judo program on psychosocial factors in typically developing and children with autism spectrum disorder: a mixed-methods study. Available at: https://stars.library.ucf.edu/honorstheses/252

Toskić, D., Lilić, L., and Toskić, L. (2014). The influence of a year-long judo training program on the development of the motor skills of children. *Act. Phys. Educ. Sport* 4, 55–58.

Ulrich, D. A. (2019). *TGMD-3: Test of Gross Motor Development: Examiner's Manual. 3rd Edn*, Austin, TX: Pro-Ed, Inc.

Walaszek, R., Sterkowicz, S., Chwała, W., Sterkowicz-Przybycień, K., Walaszek, K., Burdacki, M., et al. (2017). Assessment of the impact of regular judo practice on body posture, balance, and lower limbs mechanical output in six-year-old boys. *J. Sports Med. Phys. Fitness* 57, 1579–1589. doi: 10.23736/S0022-4707.16.06602-0

Wilmshurst, L, and Brue, AW. (2018). *The Complete Guide to Special Education: Expert Advice on Evaluations, IEPs, and Helping Kids Succeed*. London: Routledge.

Zhao, M., and Chen, S. (2018). The effects of structured physical activity program on social interaction and communication for children with autism. *Biomed. Res. Int.* 2018:1825046. doi: 10.1155/2018/1825046