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An innovative approach to the physical fitness of 10–12-year-old Armenian judokas: high-intensity functional training and results

original paper
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ABSTRACT

Purpose. Sports success depends on innovative training methods. High-intensity functional training (HIFT) incorporates weightlifting, gymnastics, aerobics, and other sports elements. Due to its innovative methodology, HIFT has gained considerable popularity. This research aimed to test the effectiveness of a HIFT-based program among 10–12-year-old judokas.

Methods. Twenty male participants (11 ± 0.64 years) were randomly assigned to either HIFT (experimental, *n* = 10) or traditional training (control, *n* = 10) groups for 40 weeks. Fitness and judo-specific skill testing (i.e., O Soto Gari and O Goshi throws) occurred pre-, mid-, and post-intervention. HIFT was implemented twice weekly for 15–20 min. The control group completed traditional physical fitness training. The training load was matched across groups.

Results. Both groups improved in pull-ups, long jumps, shuttle runs, 800-metre runs, leg raises, and judo throws. The experimental group improved significantly more on pull-ups (7.6 ± 5.6, $p = 0.024$), push-ups (20.3 ± 4.2, $p = 0.001$), squats (63 ± 8.8, $p < 0.001$), leg raises (13.3 ± 8.0, $p < 0.001$), burpees (13.2 ± 1.3, $p = 0.007$), and throws (O Soto Gari 19.71 ± 0.90, $p = 0.033$, O Goshi 20.61 ± 0.86, $p < 0.001$).

Conclusions. HIFT may improve the fitness and judo-specific skills of 10–12-year-old judokas while not negatively reflecting on the performance quality of basic techniques of judokas.

Key words: exercise prescription, judo, youth sports performance, motor skill development

Introduction

In judo, athletic prowess depends on developing and improving fundamental motor skills [1, 2]. Highly skilled competitive judokas (judo athletes) exhibit exceptional dynamic strength, muscular endurance, and anaerobic and aerobic power [3, 4]. To succeed in international competitions, judo athletes must be in excellent physical condition, which requires complex training to improve motor skills and increase physical fitness [3]. Innovative training methods are required to develop and improve the motor skills of young judo athletes.

Innovative training methods to increase the physical fitness level of judokas have been proposed with varying success [2, 5–8]. For example, Detanico et al. [8] suggested a comprehensive approach to training. Short-distance runs and jump training were used to develop agility. Throws, jumps, movement games, sports games, and various relays were used to improve high-speed abilities. Variable-pace running, cross-country running, and sports games were used to increase endurance. Exercises with simulators and rubber shock absorbers were used to help develop muscular strength. Detanico et al. [8] recommended acrobatic exercises, trampoline jumping, and exercises in pairs for agility. For developing flexibility, "bridges," bends, ropes, and exercises performed on the gymnastic wall were suggested. Many of these components can be found in high-intensity functional training (HIFT).

Judo specialists always look for the most effective methods to train young athletes. In this sense, examining the process of improving young judokas' physical fitness with HIFT is of scientific interest.

HIFT incorporates elevated-intensity functional movements, including Olympic weightlifting tech-

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niques, power training, bodyweight exercises, and aerobic conditioning [9–12]. HIFT's primary advantage resides in its capacity to concurrently stimulate various physiological systems within the human body during a singular training session [9, 11, 13]. HIFT emphasizes functional, multi-joint movements via both aerobic and muscle-strengthening exercises and can be adapted for all fitness levels and, unlike repetitive aerobic exercises, it elicits greater muscle recruitment, thereby improving cardiovascular endurance, strength and flexibility [14–15]. HIFT aims to develop general physical preparedness (i.e., fitness) across multiple fitness domains, including speed, strength, and endurance [16]. However, there is still a need to study key aspects of its application and effectiveness in training young athletes in specific sports like judo.

Some research [14, 17–20] has explored HIFT's effectiveness in increasing young athletes' physical fitness. One study found that a HIFT-based training program improved the physical fitness of both 10- and 14–16-year-old judokas [14]. Another study found that a HIFT-based training program positively affected 16–17-year-old judokas' competitive results [20]. Previous research suggests [19] that HIFT is a promising training strategy to increase general physical and judo-specific fitness among young judokas; however, it lacks critical details. For example, training load data are missing in some studies [17, 18, 20, 21]. In other studies [14, 22], which exercises were performed is unclear. Other studies [14, 19, 21–23] do not report HIFT's effect on techniques and athletic performance.

This leaves a notable gap in knowledge regarding the potential advantages and risks of implementing HIFT with younger athletes, specifically those aged 10–12. It is, therefore, imperative to ascertain whether HIFT can effectively contribute to the physical development of judokas at this critical stage of growth.

HIFT emphasises movements that are functional and mimic the demands of various sports, including judo. This can help young judokas develop the physical attributes needed to perform techniques more effectively and with greater power [24]. Emphasising functional movement patterns at a young age may help provide a stronger fitness base as the athletes continue to mature [25].

The search for innovative training methods to increase Armenian judo athletes' physical fitness is of interest [26, 27]. Implementing a successful program could contribute to improved performances in international competitions. Thus, this research aimed to examine the effectiveness of a HIFT program in increasing the physical fitness of 10–12-year-old judokas. We hypothesised that HIFT would develop a 10–12-year-old judoka's physical fitness more effectively than traditional training. We also hypothesised that HIFT would not adversely affect the quality of essential technical throw performances.

Material and methods

Design

Baseline, mid-point, and post-test testing occurred in September 2021, February 2022, and July 2022, respectively. All testing was conducted in both groups under normal conditions and included a standardised warm-up. The warm-up included neck, arm, and elbow circles, hip rotations, body circles, lunge taps, sit static lunges, low lunges, butterflies, jumping jacks, etc. Participants were allowed one practice attempt in each

Table 1. Exercises for testing the level of physical fitness of judo athletes are listed in the order in which they were performed during testing

Exercises (physical fitness)	Unit of measurement	Motor skill
Pull-ups	repetitions	muscular strength
Long jump	cm	speed-strength abilities
Push-ups (10 s)	repetitions	speed-strength endurance
Squats (60 s)	repetitions	speed-strength endurance
Leg raises on Sweden wall	repetitions	muscular strength
5 forward rolls	s	coordination
Burpees (30 s)	repetitions	speed-strength endurance
Shuttle run 4 × 10 m	s	coordination
Walk in a straight line	cm	coordination
800 m run	s	endurance
O Soto Gari (10 repetitions)	s	judo-specific fitness
O Goshi (10 repetitions)	s	judo-specific fitness

exercise except for the long jump, where three attempts were given, and the best attempt was recorded. All exercises are presented in the order they were tested (Table 1) according to the easy-to-complex principle [14], and in general, rest time ranged from 2 to 3 min between tests. Exercise testing was structured to mitigate fatigue; therefore, tests were organised using different muscle groups or intensities. All exercises were selected according to the previous research recommendations [15, 27–30].

Time-related measures were recorded with an Apple iPhone X, and the researchers counted and recorded repetitions or distances for the other measurements. The 800-metre run, shuttle run, and five forward rolls were measured in seconds to completion. Pull-ups and leg raises were recorded as the maximum repetitions possible. The long jump was recorded in the distance of the jump. Push-ups, squats, and burpees were recorded as repetitions completed in the allotted time (e.g., 10, 60, and 30 s, respectively). Walking in a straight line was recorded as the maximum distance in cm in which the participant could walk in a straight line and was used to assess dynamic balance [30]. The "O-Soto-Gari" and "O-Goshi" throws were used to measure judo-specific fitness because they are basic judo techniques. The O Soto Gari throw is a sweeping leg backward throw, and the O Goshi throw is a forward throw. The athletes performed each throw ten times, and the time to completion was measured. Participants performed the throws with predetermined height- and weight-matched pairs.

In addition, three International Judo Federation-certified experts evaluated the technique of performing the O Goshi throw of the athletes before and after the training program. Their evaluation was done according to the following criteria created by the researchers for the study: "excellent" – 9–10 points, "good" – 7–8 points, "average" – 5–6 points, "bad" – 3–4 points, and "very bad" 1–2 points. The highest score was given when the technical throw was performed with clear, precise, confident, firm, correct grip, maximum width, consolidation of movements, correct cushioning, and fixation of the legs at the finish. The hands and feet were coordinated, and the throw was performed with the necessary rhythm. There was no tension in individual body parts and no mistakes. Throw performance was recorded with a smartphone (Apple iPhone X) from around three metres away and reviewed by the three experts. The video recording allowed the experts to watch the throws performed by each athlete at different speeds (also in slow motion) to ensure an accurate and objective assessment. The O Goshi throw was chosen for the study because it is considered one of the basic throws of judokas, and the athletes already knew the technique of performing it according to their age.

Participants

Participants were recruited from the "Youth Sports and Cultural Training Center after Vahe Zakaryan" in Hrazdan, Republic of Armenia. All male judokas aged 10–12 from the sports school with no injuries were eligible to participate. Due to the pilot nature of this study, we did not compute an a priori power analysis [31]. When justifying the sample size, we considered the number of judokas of this age in the only sports school in the city of Hrazdan. Twenty male participants, age 11 ± 0.64, were randomly assigned to the HIFT (experimental) or standard training (control) groups. Each group had ten athletes. Their competition weight categories varied (i.e., 24, 27, 30, and 34 kg), and their height ranged from 147–155 cm. Participants had yellow, orange, or green judo belts. Children in both groups were considered active and participated in 135 min of physical activity per week through physical education classes. Researchers were granted permission from the sports school to conduct the experiment, and an informational meeting was held before the study began. Study participants, their parents, and the school's administration attended the meeting.

Informed consent was obtained from all individuals included in this study. Parents, being familiar with the purpose of the research, the conditions of its conduct, and the organisation conducting the research, gave consent to their child's participation in the given research, processing, and publication of their data. Furthermore, the children, in turn, were familiar with the purpose of the research, the conditions of its conduct, and the organisation conducting the research, and gave their consent to participate in the given research process and publication of their data.

Procedures

Participants in both groups completed 135 min (2.25 hours) of physical activity weekly in physical education classes. The recommended annual volume of physical fitness for the Republic of Armenia children's and youth sports schools is 66–88 hours, and judo-specific fitness is 55–66 hours per year. However, those numbers are recommended loads and not mandatory. After consulting with other judo coaches, we discovered many used a lesser volume. Considering this, we developed our intervention to include fewer hours than the national recommendations. From September to

January, study participants received 15.1 hours of physical fitness training, of which 10 hours were allocated to HIFT for the experimental group. This included two 10–20-minute sessions per week of HIFT held immediately after the primary judo training. From February to June, the physical fitness training load in both groups was 16.1 hours, of which 11 hours were allocated to HIFT for the experimental group. Thus, across the entire training duration (September–June), the total physical fitness training load was 31.2 hours, of which, for the experimental group, 21 hours were HIFT. A differentiated approach to load was utilised best to accommodate characteristics inherent to the age of participants.

In the control group, the usual methods recommended by the training program were used (e.g., during one training session, perform 50 pull-ups or 100 push-ups, running 2000 m, etc.) with the same duration and frequency as recommended in the experimental group (25–35 min per week). In the experimental group, "Tabata," "AMRAP," "21-15-9", "10-8-6-4-2," and in some cases, Workouts of the Day (WOD) consisting of various exercises were used during HIFT. During the third training session of the week, instead of HIFT, the trainers were free to choose any method to improve physical fitness, including mobile games and sports games, lasting 15 min, the load of which was 10.2 hours during the intervention. A total of 80 HIFT sessions were conducted.

During the training year, mid-point test analysis [32] demonstrated that some vital motor skills for adolescent judokas, particularly muscular strength, endurance, speed-strength endurance, and coordination, did not reliably improve in the groups. Therefore, we adjusted the load of these motor skills for the experimental group. The volume of running exercises, mainly outdoors, increased as the weather conditions improved. From September to January, the total volume of running exercises was 8 min; from February to June, the total volume of running exercises increased by 400% to 40 min.

After consulting with the coach, we decided to increase the frequency and volume of pull-up exercises in the experimental group. From September to January, the athletes performed approximately 60 pull-ups with the Tabata method (intervals of 20 s of work followed by 10 s of rest) for 12 min. Their volume increased by approximately 567% from February to June, amounting to 400 pull-ups. Exercises used to develop coordination ability increased from 40 min (primarily using the Tabata method) in September–January to 60 min in February–June using the "Speed Ladder," along with rolls, shuttle runs, and different types of hurdles.

Statistical analyses

Data analyses were conducted with SPSS 27 (IBM Corp., Armonk, NY, USA). Data was reported as mean ± standard deviation. Outliers were checked using a visual inspection of box plots. Normality was checked using the Shapiro–Wilk test. Levene's test was used to assess the homogeneity of variance, while the homogeneity of covariance was checked using Box's M test. Mauchly's test of sphericity tested for violations of the assumption of sphericity. Data that met normality assumptions at two time points were considered normal according to existing standards [33]. Independent samples *t*-tests were conducted to examine between-group differences at baseline. Cohen's *d* was used to estimate effect sizes interpreted as trivial (0.00–0.20), small (0.21–0.50), medium (0.51–0.80), and large (> 0.80). A mixed model analysis of variance (ANOVA) was conducted to test the interactions between the three measurements and two groups. Partial eta-squared (η^2_p) was used to estimate effect sizes, interpreted as small (0.01), medium (0.06), and large (0.14). Within-group analysis was conducted using repeated measures ANOVA and between-group analysis for each time point using independent *t*-tests. Bonferroni's post-hoc test was used to determine the significance level in pairwise comparisons. Cohen's *d* determined the effect size for pairwise comparisons. Data that did not meet normality assumptions were tested using the Friedman and Wilcoxon signed-rank tests. Statistical significance was set at $p \leq 0.05$.

Results

Means and standard deviations for all time points are reported in Table 2. Of note, differences between baseline and midpoint assessments have been previously published [32]. At baseline, there were significant differences between the experimental and control groups for push-ups ($t(18) = -2.91$, $p < 0.01$, 95% CI [–2.26, –0.32], Cohen's $d = 1.30$), squats ($t(18) = -3.40$, $p < 0.01$, 95% CI [–2.51, –0.50], Cohen's $d = 1.52$), and the walk in a straight line ($t(18) = 3.14$, $p < 0.01$, 95% CI [0.40, 2.37], Cohen's $d = 1.40$) fitness measurements.

Mixed-model ANOVAs tested for significant interactions between times (i.e., baseline, midpoint, and post-test) and groups (experimental or control). Statistically significant interactions (time * group) were observed for pull-ups ($F = 4.22$, $p = 0.024$, $\eta_p^2 = 0.22$), push-ups ($F = 8.30$, $p = 0.001$, $\eta_p^2 = 0.36$), squats ($F = 14.03$, $p < 0.001$, $\eta_p^2 = 0.48$), leg raises ($F = 8.79$, $p < 0.001$, $\eta_p^2 = 0.37$), burpees ($F = 5.90$, $p = 0.007$, $\eta_p^2 =$

Table 2. Changes in physical fitness measurements at each time point by experimental and control group

Variable	Unit of measurement	Experimental group				Control group				Between-group		
		baseline[1] (mean ± *SD*)	midpoint[2] (mean ± *SD*)	posttest[3] (mean ± *SD*)	within-group[#]	baseline[1] (mean ± *SD*)	midpoint[4] (mean ± *SD*)	posttest[5] (mean ± *SD*)	within-group[##]	baseline	midpoint	posttest
Pull-ups[†]	repetitions	4.6 ± 3.8	6.1 ± 4.8	10.4 ± 8.4[a,b]	$F = 11.11$ $p = 0.001$ $\eta_p^2 = 0.61$	5.1 ± 5.0	5.3 ± 5.4	7.6 ± 5.6	$F = 2.95$ $p = 0.081$ $\eta_p^2 = 0.27$	$t = -0.25$ $p = 0.805$ $d = 0.11$	$t = 0.32$ $p = 0.756$ $d = 0.15$	$t = 0.40$ $p = 0.31$ $d = 0.40$
Long jump	cm	175.9 ± 13.9	178.1 ± 17.3	187.1 ± 16.6	$F = 6.22$ $p = 0.012$ $\eta_p^2 = 0.47$	168.7 ± 13.9	174.0 ± 17.1	179.1 ± 16.2	$F = 3.57$ $p = 0.052$ $\eta_p^2 = 0.31$	$t = 1.16$ $p = 0.262$ $d = 0.518$	$t = -0.49$ $p = 0.629$ $d = 0.24$	$t = 1.04$ $p = 0.316$ $d = 0.488$
Push-ups (10 s)	repetitions	15.8 ± 3.6	20.0 ± 3.4	20.3 ± 4.2	$F = 4.74$ $p = 0.027$ $\eta_p^2 = 0.40$	20.5 ± 3.6	18.1 ± 3.6	17.4 ± 3.8	$F = 3.521$ $p = 0.054$ $\eta_p^2 = 0.31$	$t = -2.91$ $p = 0.009$ $d = 1.303$	$t = 1.12$ $p = 0.281$ $d = 0.544$	$t = 1.53$ $p = 0.147$ $d = 0.719$
Squats (60 s)	repetitions	51.6 ± 3.0	53.8 ± 11.6	63.0 ± 8.8[a, b]	$F = 8.76$ $p = 0.003$ $\eta_p^2 = 0.56$	58.4 ± 5.6	58.3 ± 8.9	53.4 ± 8.5[b]	$F = 4.68$ $p = 0.025$ $\eta_p^2 = 0.37$	$t = -3.40$ $p = 0.009$ $d = 1.519$	$t = -0.92$ $p = 0.372$ $d = 0.447$	$t = 2.35$ $p = 0.032$ $d = 1.107$
Leg raises on Sweden wall	repetitions	11.2 ± 1.8	19.4 ± 8.3)[a]	24.6 ± 9.6[a]	$F = 18.88$ $p < 0.001$ $\eta_p^2 = 0.73$	11.5 ± 5.9	13.1 ± 7.6[1]	13.3 ± 8.0	$F = 0.28$ $p = 0.763$ $\eta_p^2 = 0.03$	$t = -0.13$ $p = 0.895$ $d = 0.060$	$t = 1.62$ $p = 0.125$ $d = 0.789$	$t = 2.70$ $p = 0.016$ $d = 1.273$
5 forward rolls	s	5.4 ± 0.4	5.1 ± 0.5)	4.9 ± 0.3	n/a	5.70 ± 1.1	5.5 ± 0.7	5.4 ± 0.9	n/a	n/a	n/a	n/a
Burpees[‡] (30 s)	repetitions	12.1 ± 1.8	13.6 ± 1.1)	13.2 ± 1.3	$F = 3.94$ $p = 0.048$ $\eta_p^2 = 0.40$	13.3 ±3.1	11.0 ± 2.3	11.0 ± 2.2	$F = 3.37$ $p = 0.060$ $\eta_p^2 = 0.30$	$t = -1.07$ $p = 0.298$ $d = 0.479$	$t = 2.88$ $p = 0.014$ $d = 1.338$	$t = 2.63$ $p = 0.018$ $d = 1.238$
Shuttle run 4 × 10 m	s	12.0 ± 0.4	10.5 ± 0.7[a]	10.6 ± 0.4[a]	$F = 47.76$ $p < 0.001$ $\eta_p^2 = 0.87$	11.8 ±0.5	10.4 ± 0.5[1a]	10.8 ± 0.6[a]	$F = 47.53$ $p < 0.001$ $\eta_p^2 = 0.86$	$t = 1.22$ $p = 0.237$ $d = 0.547$	$t = 0.30$ $p = 0.766$ $d = 0.147$	$t = -0.84$ $p = 0.416$ $d = 0.394$
Walk in a straight line	cm	140.9 ± 68.3	124.8 ± 53.7	108.2 ± 28.7	n/a	63.1 ±38.7	75.0 ± 34.2	83.6 ± 27.2	n/a	n/a	n/a	n/a
800 m run	mm:ss	4:31 ± 0:30	4:46 ± 0:39	4:10 ± 0:29[b]	$F = 6.31$ $p = 0.013$ $\eta_p^2 = 0.51$	4:49 ±0:21	4:48 ± 0:23	4:24 ± 0:23[a,b]	$F = 11.45$ $p = 0.002$ $\eta_p^2 = 0.66$	$t = -1.50$ $p = 0.151$ $d = 0.671$	$t = -0.11$ $p = 0.915$ $d = 0.057$	$t = -1.09$ $p = 0.294$ $d = 0.528$
O Soto Gari (10 repetitions)	s	28.9 ± 3.8	22.7 ± 3.0[a]	19.7 ± 2.7[a]	$F = 38.98$ $p < 0.001$ $\eta_p^2 = 0.85$	27 ±4.6	24.6 ± 5.5	22.0 ± 2.5	$F = 3.70$ $p = 0.048$ $\eta_p^2 = 0.32$	$t = 1.02$ $p = 0.323$ $d = 0.454$	$t = -0.87$ $p = 0.397$ $d = 0.424$	$t = -1.85$ $p = 0.082$ $d = 0.874$
O Goshi (10 repetitions)	s	29.0 ± 5.0	25.0 ± 3.8[a]	20.6 ± 2.6[a]	$F = 23.95$ $p < 0.001$ $\eta_p^2 = 0.77$	28.9 ±2.6	29.6 ± 2.9	28.9 ± 3.6	$F = 0.46$ $p = 0.643$ $\eta_p^2 = 0.05$	$t = -0.17$ $p = 0.868$ $d = 0.076$	$t = -2.87$ $p = 0.012$ $d = 1.393$	$t = -5.60$ $p < 0.001$ $d = 2.638$

[1] $n = 10$; [2] $n = 8$ except burpees and 800 m run where $n = 7$; [3] $n = 9$; [4] $n = 9$, except for 800 m run where $n = 7$; [5] $n = 9$, except 800 m run where $n = 8$
\# F(2,16) except for 800 m run where F(2,12); ##F(2,14) except for burpee and 800 m run where F(2,12)
† not normal at mid-point; ‡ not normal at baseline
[a] significant difference from baseline, [b] significant difference from midpoint
n/a – failed normality assumptions, see results below

0.30), O Soto Gari throws (F = 3.85, p = 0.033, η_p^2 = 0.20), and O Goshi throws (F = 16.24, p < 0.001, η_p^2 = 0.52). No significant interactions were observed for the long jump (F = 0.35, p = 0.706), shuttle run (F = 2.90, p = 0.07), and 800-metre run (F = 0.76, p = 0.048).

Significant within-group differences were found for all fitness tests in the experimental group and squats, shuttle runs, 800-metre runs, and the O Soto Gari throws in the control group (see Table 2). For the experimental group, pull-ups were significantly greater at post-test than baseline (p = 0.026) and midpoint (p = 0.021); squats were significantly greater at the post-test than at baseline (p = 0.009) and midpoint (p = 0.024); leg raises increased significantly from baseline to midpoint (p = 0.021) and baseline to post-test (p = 0.001); shuttle run times improved significantly from baseline to midpoint (p < 0.001) and baseline to post-test (p < 0.001); 800-metre run times improved significantly from midpoint to post-test (p = 0.002); time to complete the O Soto Gari throws was significantly faster at midpoint and post-test than at baseline (p = 0.002 and p < 0.001, respectively); and, the O Goshi throws were completed significantly faster at midpoint and post-test than at baseline (p = < 0.001 and p = 0.009, respectively). For the control group, squat repetitions were significantly fewer at post-test than at midpoint (p = 0.009); shuttle run times improved significantly from baseline to midpoint (p < 0.001) and baseline to post-test (p < 0.001); 800-metre run times were significantly faster at post-test than at baseline (p = 0.048) and midpoint (p = 0.005); and time to complete the O Soto Gari throws was significantly faster at post-test than at baseline (p = 0.034).

Independent samples t-tests were conducted to explore between-group differences at each time point. At baseline, the control group completed significantly more push-ups and squats than the experimental group (Table 2). At the midpoint, the experimental group completed significantly more burpees and was faster in O Goshi throw performance than the control group (Table 2). The experimental group performed significantly more squats, leg raises, and burpees and had faster O Goshi throws than the control group (Table 2).

The forward rolls and walk-in a straight-line fitness assessment data failed normality assumptions; thus, the Friedman test was employed to explore the main effects of times and groups. All participants completed the forward rolls significantly faster over time ($\chi^2(2)$ = 10.94, p = 0.004). The Wilcoxon sign-rank test revealed a significant improvement from baseline to post-test (Z = 2.90, p = 0.004). When comparing groups, only the experimental group had significant differences over time in the forward rolls, $\chi^2(2)$ = 9.00, p = 0.011 compared to the control group, $\chi^2(2)$ = 4.67, p = 0.097. The Wilcoxon sign-rank test revealed statistically significant differences in the time to complete the forward rolls in the experimental group from baseline to the post-test (Z = 2.67, p = 0.008). No significant differences were observed for walking in a straight-line over time among all participants ($\chi^2(2)$ = 0.12, p = 0.94). The Wilcoxon sign-rank test revealed no significant changes between time points (i.e., baseline to midpoint [Z = 0.000, p = 1.00], baseline to post-test [Z = 0.05, p = 0.962], and midpoint to post-test [Z = 0.07, p = 0.948]). Neither the experimental ($\chi^2(2)$ = 1.75, p = 0.417) nor control group ($\chi^2(2)$ = 0.89, p = 0.641) demonstrated significant differences over time or between timepoints for walk in a straight-line (experimental group: baseline to midpoint [Z = 1.12, p = 0.263], baseline to post-test [Z = 1.25, p = 0.213], midpoint to post-test [Z = 0.98, p = 0.327]; control group: baseline to midpoint [Z = 0.53, p = 0.594], baseline to post-test [Z = 1.13, p = 0.260], midpoint to post-test [Z = 0.89, p = 0.374]).

Before the experiment, the efficiency of movement evaluations was given by the experts for the experimental and control groups. Rankings did not differ significantly between groups (t = 0.292, p = 0.387). The evaluation was also made at post-test without significant differences (t = 0.639, p = 0.266). However, there was a significant main effect of time for improvement in O Goshi throw efficiency across both groups, $F(1, 15)$ = 31.06, p < 0.001.

Discussion

This study aimed to determine the effectiveness of HIFT on the physical and judo-specific fitness of 10–12-year-old judokas. To achieve that goal and to discover the effectiveness of HIFT, it was necessary to compare the effectiveness of our proposed and traditional approaches. For this purpose, experimental and control groups were formed, using HIFT in the first group and based on the traditional approach to training in the control group.

We hypothesised that HIFT would improve the judoka's physical and judo-specific fitness more than traditional training. In support of our hypotheses, significant group-by-time interactions were found for pull-ups, push-ups, squats, leg raises, burpees, and both judo throws. Overall, the athletes in the experimental group significantly improved in every fitness and judo-specific measurement, while the control group did significantly fewer squats but improved their shuttle run, 800-metre run, and O Soto Gari throw times. These significant differences occurred despite both groups reducing their training volume from the Armenian national recommendations.

The experimental group's significant improvements in pull-ups, push-ups, squats, burpees, and leg raises agree with previous research findings that HIFT improves muscular strength because it is performed at high intensity using the principles of progressive overload and time under tension [34]. The current study utilised Tabata and AMRAP-style training to promote muscular strength gains. In contrast, the control group decreased the number of squats performed despite performing more push-ups and squats than the experimental group at baseline.

Speed and endurance improvements in the experimental group were echoed in the control group, as both groups improved their shuttle run and 800-metre run times. The latter may be related to the weather conditions, because after the melting of the snow, outdoor running exercises were added in the control group as well, which contributed to the improvement of indicators in the mentioned exercises. Within the HIFT group, the Tabata-style workouts may have been instrumental in these improvements. We alternated running short, high-intensity sprints (for 20 s) with short (10-second) rest periods. Research [35] has shown that HIFT-based training (high-intensity intervals) paired with anaerobic training increases aerobic capacity. Our results are in alignment with this idea.

Both judo-specific fitness measures significantly improved in the experimental group, while only the O Soto Gari throws improved for the control group. Speed, strength, and endurance are required to complete both throws and, thus, may have been facilitated through the Tabata workouts performed during HIFT. However, there were no significant differences between groups in the expert's evaluation of the athlete's efficiency in throw performance. This finding demonstrates that both groups preserved the technique, even though throws were performed more quickly. This finding agrees with previous research [14] that also demonstrated improvements in technical performance after a HIFT program among young judokas.

Our findings agree with a small, growing body of research describing HIFT's effectiveness at increasing general and judo-specific fitness [12, 17–20, 32]. For example, Osipov et al. [20] found that regular HIFT training positively affected judoka competitive results. While we did not study competitive results, it is reasonable to think that the athletes in the experimental group would improve in competition.

Several study strengths and limitations must be noted. Study strengths include matching training volume across both the experimental and control groups. Additionally, the researchers administered every HIFT session to ensure it was delivered according to the study design. Moreover, expert assessment of the O Goshi and O Soto Gari throws was novel to this study and could be implemented in future studies. However, study limitations exist. Our relatively small sample size may not have provided adequate statistical power. Our study's generalizability is limited since we had a small sample size of only 10–12-year-old male judokas. Controlling the participants' physical activity outside of the study was impossible.

Nonetheless, we delivered an effective intervention despite having limited equipment. Most sports schools in Armenia lack essential items such as free weights (barbells and dumbbells), additional weight plates, climbing ropes, and other necessary equipment. Implementing HIFT despite these shortages can be highly beneficial and be a model for other sports schools facing similar limitations. The successful application of HIFT in resource-constrained environments demonstrates its adaptability and potential value for facilities with incomplete training equipment.

The findings of this research provide valuable insight that may be used to inform future research opportunities. For example, future research should examine whether HIFT can help reduce judokas' injury risks by strengthening stabiliser muscles and improving overall body resilience. Future research could examine the impact of HIFT on energy system utilisation during judo competitions. Understanding how HIFT affects aerobic and anaerobic capacity and recovery between high-intensity efforts can provide insights into optimising performance and training regimens. Skill transfer could also be studied to investigate how HIFT movements, such as Olympic weightlifting or gymnastics exercises, positively or negatively affect specific judo techniques and determine which HIFT exercises have the most significant carryover to judo skills.

Innovative training methods are required to ensure judokas reach their full competitive potential. Meanwhile, further research should determine if the current findings are in contradiction with recent evidence suggesting that an excess childhood/adolescent specialised practice may hinder athletes' long-term development through overuse injuries, burnout, suboptimal athlete-sport match, and limiting long-term learning capital [36].

Conclusions

Training intensity for children in sports with high technical and tactical demands should be carefully managed. The results of the current study suggest that HIFT can be effectively implemented for young athletes. Our pilot study shows how HIFT, which combines bodyweight exercises, cardiovascular exercises, gymnastics and functional movements, can be successfully adapted for young judokas. Indeed, HIFT significantly improved general and judo-specific fitness in 10–12-year-old judokas. In particular, we observed significant improvements in muscular strength (i.e. pull-ups and leg raises), speed-strength endurance (i.e. push-ups, squats, burpees), and judo-specific fitness (i.e. O Soto Gari and O Goshi throws). Thus, our study suggests that younger athletes can improve their fitness after HIFT and provides more detail on training loads (methods used, exercises, volumes, and intensities) than previous research. Success in competition is the goal of competitive young judokas and HIFT methods may be a tool to facilitate success.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Armenian State Institute of Physical Culture and Sport Ethics Committee (approval No.: 2023-PT-2). Moreover, adherence to the International Journal of Exercise Science standards was maintained throughout this research [32].

Informed consent

Informed consent has been obtained from all participants and their parents included in this study.

Conflict of interest

The authors state no conflict of interest.

Disclosure statement

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