A Novel Approach to Safe Special Fitness Testing in Judo Players

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A Novel Approach to Safe Special Fitness Testing in Judo Players

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Abstract: Background: Measurements of physical fitness indices obtained in laboratory tests using an ergometer or a treadmill are very accurate, but they involve selected groups of muscles and do not reproduce the structure of the sport-specific exercise in judo. For this reason, researchers seek for the tests that use movements similar to the characteristic offensive techniques used during competitions (i.e. throwing). The most commonly recommended is the seoi-nage throwing test, known as SJFT (special judo fitness test).The aim of the study was to develop a new test in which uke is replaced by a dummy, in order to reduce the injury rate and ensure the safety of the participants. Methods: During the 3-week period, competitors from different weight classes performed at the beginning and then after

the 2-week period one 1-minute series of continual dummy throws using the o-goshi technique and the seoi-nage technique. Post-exercise physiological responses (heart rate [HR] and blood lactate levels [La]) were evaluated. Results: Significant improvements were reported in o-goshi performance level after the training period. Physiological responses to exercise did not change significantly after training sessions. On both measurement days, post-exercise La levels were similar for o-goshi and seoi-nage throws, whereas post-exercise HR was significantly greater after seoi-nage throws. Conclusions: The dummy throwing test can be a recommended alternative to uke throwing due to the elimination of the risk of injuries to practising athletes.

Keywords: judo, field tests, fitness, throws, head injuries,

Background

Combat sports constitute a group of sports that are often practiced in Poland. In this group, judo is the most popular sport practiced at both competitive and amateur level (1). It is necessary for the development of this sport to control the level of special and technical fitness in the implementation of basic elements that allow for success during the fight (2). During an official judo bout, lasting several minutes, various techniques are used to gain an advantage over the opponent. Winning before the time limit (4 minutes) is determined by the successful application of one of the following techniques: immobilization on the ground, choking, arm lock, and throwing the opponent on the mat in such a way that he or she falls on his back. It is also possible to lose a fight by disqualification or loss of points if the athlete is awarded a penalty for rule infringements during the fight (3,4). Successful offensive actions during a judo fight require a lot of speed, strength, and a very good technique (5,6). The first two physical characteristics can be evaluated with high accuracy using laboratory exercise tests

with an ergometer and/or a treadmill (7). They allow for the estimation of the anaerobic or aerobic capacity depending on the time and load used for these efforts. However, laboratory results of elite judo athletes do not always show relationships with competitive performance (8). This may be due to the different motor and movement backgrounds used in laboratory tests of general fitness in relation to sports fight in judo. In these tests, selected groups of muscles of the upper or lower limbs are involved in the effort, while during judo fights the muscles of the whole body perform various short bouts of exercise at maximum intensity (9–12). Therefore, tests based on the performance of technical elements and parts of judo fight seem more appropriate. Furthermore, judo belongs to the group of open-skills sports. Therefore, in addition to physical fitness, the accuracy of decision-making in tactical problem-solving has a great effect on competitive performance and these skills should be developed through training (13). Seeking other predictors of success in judo revealed a wide range of technical skills as the basis, which is expressed in a repertoire of different types of throws used during competitions (14). For this reason, uchi-komi, nage-komi (drills of throws) and perfecting the skills of using them during sparring sessions (randori, kakari-geiko) play a dominant part in judo training programs (15). According to some authors, such exercises improve specific fitness and psychomotor abilities, although their excess may overload the hand muscles and decrease their strength (16).

Within the framework of the coaching control in judo, the analysis of the temporal and material structure of the fight is applied (17,18), the technical-tactical indicators of activity, effectiveness, and efficiency of the fight are calculated (14,19–21), and biomechanical aspects of technique are evaluated (22,23). There is also a need for ongoing monitoring of specific physical performance and effectiveness of techniques learned and speed of performing these techniques during the fight. Special and technical fitness tests have been used to evaluate such activities. They allow coaches to obtain data on the degree of technical skills acquired by

athletes and at the same time indicate the level of development of strength, speed, and special endurance. When designing such tests, one should use the technical elements characteristic for a given sport (24). In judo, the development and standardization of the field tests should be based on the performance of basic offensive technical actions, i.e. throws.

A few dozen of different throwing techniques are known in judo (25,26). Since the introduction of new rules (2013) for official competition, several studies have analyzed the effectiveness of these techniques in competitive settings both by gender and weight class (27–29). Ippon seoi-nage, which is the most popular throwing technique in judo, was chosen to perform a reliable special fitness test (30,31).

The procedure of such a test was first presented in a study by Sterkowicz and Ambroży on the physical fitness of ju-jitsu competitors (32). Furthermore, Sterkowicz standardized the test, determined its validity and reliability, supplemented it with an index of physical fitness, and implemented the test into practice while defining it as the Special Judo Fitness Test (SJFT)(33).

It was based on standardized sets of throws involving sparring partners using the seoi-nage technique. The advantages of the use of the test have been described in several publications emphasizing its effectiveness in the assessment of special preparation of judo competitors (34–42).The method of performing the test was as follows. After a 5-minute warm-up and performing the ippon-seoi-nage throws several times at a slow pace, three exercise periods (A: 15 s; B and C: 30 s each) were performed, separated by 10-second breaks. In each period/set of throws, the thrower (tori) is evaluated based on the maximum number of ippon-seoi-nage throws performed on two partners (ukes A and B) standing on the mat 6m apart. Both uke A and uke B should be of similar height and weight as the tori. Heart rate is measured immediately after and one minute following the test. This study evaluated the Index in SJFT*:*

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$$SJFT\ Index = \frac{Final\ HR\ (bpm) + HR1\min(bpm)}{Throws\ (N)} \quad \text{eq.1}$$

99

100 where:

101 Final HR – heart rate recorded immediately after the test. HR1 min – heart rate
102 obtained 1 minute after test. Throws – number of throws completed during the test. The
103 response to exercise was recorded using S-610i heart rate monitor (43).

104 It can be speculated whether it is possible to perform this test with a different
105 technique, for example using the favorite technique (tokui-waza) (44). Numerous studies have
106 revealed a weight class-dependent total number of throws in the SJFT in three consecutive
107 sets lasting 15-30-30 s separated by 10-second intervals. This allowed for developing
108 reference ranges for both sexes by weight class and specific fitness level. The SFJT score has
109 been shown to correlate with aerobic capacity as measured by laboratory exercise tests (45).
110 The diagnostic value of SJFT and good reproducibility of results demonstrated in the test-
111 retest procedure suggest the use of this tool for the assessment of performance also in ju-jitsu
112 athletes (46), wrestlers (47,48), and young judokas during preparation for important
113 tournaments (49).

114 It should be emphasized, however, that too frequent use of the SJFT test and nage
115 komi exercises has a harmful effect on the uke's health. A study using a dummy equipped
116 with sensors showed significant accelerations of the head on contact with tatami after
117 performing osoto-gari and ouchi-gari throws (50,51). Such microtrauma is similar to repeated
118 blows to the head as in a boxing fight and can lead to damage to the brain and cervical spine
119 (52,53). The exposure of uke's brain to the acceleration associated with uke's rotation during
120 the throw was also studied for various tai-otoshi, seoi-nage, osoto-gari and ouchi-gari

121 techniques.The highest mean accelerations were reported for osoto-gari and the lowest for
122 seoi-nage (54). During the throws on a special device imitating the human body performed by
123 a Japanese judo expert, the maximum accelerations for the head upon contact with the mat
124 exceeded many times the value of the gravitational acceleration (G=9.81 kg*m*sec -1)
125 (30,55). Judo athletes have mastered the techniques of falling to the ground (ukemi), which
126 significantly reduce the exposure of the uke's head to the impact with the mat (56), whereas in
127 less technically proficient judokas, repeated contact of the head with the mat during throws
128 poses a significant risk of injury (30,57). Athletes under 20 years of age are mainly at risk of
129 serious neck and/or head injuries. Therefore, 3 years before the planned IO 2020 in Tokyo,
130 Japanese researchers called for more effective prevention of such cases both during training
131 and competitions (58).

132 In seeking the traditional judo throwing exercises (nage-komi) which are safer for the
133 thrown athletes and performance of special fitness tests, it is worth considering the possibility
134 of using grappling dummies, as it is the case in wrestling. A group of judo and combat sports
135 experts attempted to validate an alternative SJFT test using dummies and the o-goshi throwing
136 technique (Figure 1 and Figure 2).

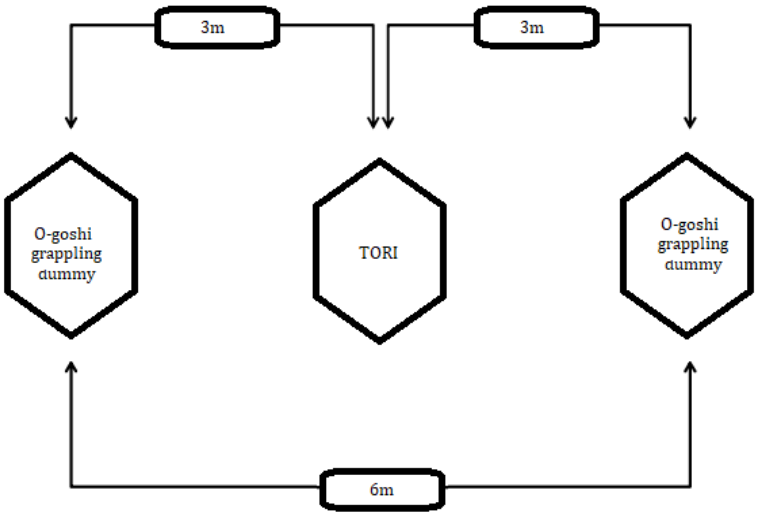

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Figure 1. Positioning in the Special Fitness Test in Combat Sports

Source: author's own elaboration

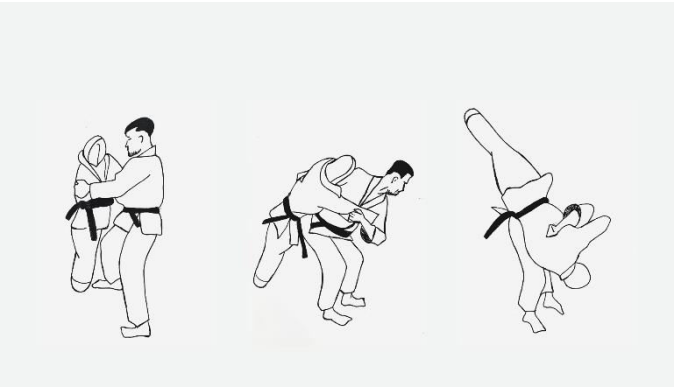

Figure 2. O-goshi throw performed with a grappling dummy

Source: author's own elaboration

The aim of the study was to verify whether a shorter 1-minute (2 times for 30 seconds) throwing test using two grappling dummies (not performed on uke partners) and the o-goshi technique, performed in a spatial arrangement as the SJFT test presented earlier has a similar diagnostic value and can be used alternatively to assess the special fitness in judo and ju-jitsu. The test was named Special Fitness Test in Combat Sports (SFTCS).

Materials and Methods

A group of fifteen athletes, three each from five weight classes (-60, -66, -81, -90, and -100kg) aged 19-24 years with a mean body height of 179.1±5.1cm, were examined during a 3-week training camp in the middle of the training and competition season (August). The athletes did not follow a restrictive diet, and therefore, the mean body weight before (79.4±14.6 kg) and after the camp (78.7±14.0 kg) was similar. Three participants were selected from each weight category, due to the availability of players during the training camp and the requirements regarding the sports level (minimum 1st sports class and judo master's

158 degree). Training experience of study participants was 8.6±0.97 years. Body height was
159 measured with a Martin-type anthropometer. Body weight was measured on a Beurer glass
160 diagnostic scale type BG17, max 150 kg, d = 100 g (Beurer GmbH Germany, limited edition
161 2010).

162 Verification of the test was conducted in three stages:

163 1. At the beginning of the camp, on two consecutive days, the athletes performed the
164 tests in randomized order according to the temporal formula (15+30+30 s) and spatial formula
165 (distance between ukes or grappling dummies of 6 meters, tori thrower in the middle of them)
166 just as it is the case during the classic SJFT test. Efforts consisting in the performance of a
167 maximum number of throws using the o-goshi technique on a dummy weighing
168 approximately a third of the athlete's body weight (in our study, dummies with heights
169 ranging from 150 to 170 cm and weights from 20 to 40 kg, respectively, were used), with the
170 center of gravity located at a distance of 111 to 131 cm from the base, or throws using the
171 seoi-nage technique involving alternately two partners (ukes) from the same weight category.
172 The tests aimed to verify whether changing the partner to a grappling dummy and the
173 throwing technique from seoi-nage to o-goshi would significantly affect the number of
174 techniques performed by the athlete during the test. Before the first o-goshi test, the athletes
175 performed preliminary trials several times to technically master the effort structure with the
176 dummy, while they were previously familiarized with the seoi-nage technique performed on
177 sparring partners. After completion of both tests performed according to the classic SJFT test
178 formula, HR1 and HR2 were measured and the SJFT Index was calculated. The index of
179 special fitness =(HR1 +HR2) /total throws was calculated for each test.

180 2. On two consecutive days, also in randomized order, subjects performed two
181 different 1-minute tests (30+30 s, with a 10 s break) before noon. The maximum number of o-
182 goshi throws performed on the dummy (New SJFT) and seoi-nage throws with the

183 involvement of two training partners (ukes) of the same weight category alternately, standing
184 between the tori, as it is the case during the classic SJFT test, were recorded. The Index SJFT
185 was also calculated.

186 3. After a 2-week period in which the athletes practiced both types of throwing every
187 few days, the throwing tests were repeated following the same procedure. Using an electronic
188 pulse oximeter, heart rate was measured immediately after the completion of each test (HR1)
189 and at 1 minute of post-test recovery (HR2). At 5 minutes after completion of the tests,
190 capillary blood was obtained from the earlobe for determination of lactate levels (La) using
191 Dr. Lange (Germany) test kit. The index of special fitness =(HR1 +HR2) /total throws was
192 calculated for each test.

193 Two-way analysis of variance (throw type x test date) was used to compare the mean
194 variables at both dates, and then Bonferroni post-hoc test was applied. Calculations were
195 performed on logarithmic data with significance set at 0.05.

196 To evaluate test validity, the total number of throws and the SJFT Index were
197 compared in tests performed according to the classic SJFT formula with the use of training
198 partners and dummies. The correlations between the results of the SJFT test and the SFTCS
199 performed at the beginning of the study and the results obtained in SFTCS at the end and the
200 results of ju-jitsu athletes were then determined (59). The r-Spearman rank correlation was
201 used. To determine the reliability of the proposed version of the test, the results of the tests
202 performed at the beginning and the end of the training camp using the test (SFTCS) were
203 compared by evaluating the differences and statistical error.

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211 **Results**

212 Descriptive statistics and results of statistical analysis for the study variables are presented in

213 Table 1.

214 Table 1**.**Task performance expressed as a number of throws, blood lactate levels (mM) and

215 heart rate values (bpm).

Variable	Type of throw	Testing 1	Testing 2	p-value
Total throws	seoi-nage	21.1±0.9	22.0±1.4	0.488
	o-goshi	21.5±2.1	23.9±1.7	0.000
	p-value	1.00	0.003	
HR1	seoi-nage	174±10.1	172.1±10.3	1.00
	o-goshi	157.7±10.7	154.8±10.7	1.00
	p-value	**0.000**	**0.000**	
HR2	seoi-nage	131.3±6.1	126.1±5.7	0.205
	o-goshi	115.1±7.4	107.6±6m7	0.005
	p-value	**0.000**	**0.000**	
Index of fitness	seoi-nage	14.5±0.8	13.6±1.1	0.096
	o-goshi	12.8±1.5	11.0±1.0	0.000
	p-value	**0.000**	**0.000**	
LA (lactate in blood)	seoi-nage	11.3±1.3	11.2±0.9	1.00
	o-goshi	10.6±1.3	10.6±1.0	1.00
	p-value	0.446	0.552	

216 Statistical analysis revealed a significant improvement in physical adaptations to the throwing

217 test performed with the o-goshi technique after approximately 2-week training. No

218 improvement was found for the seoi-nage test. After the training period, the index of fitness

219 significantly improved (by 14%) in the o-goshi test, whereas in the seoi-nage test, the relative

220 improvement of 6% was not statistically significant. The greatest differences between the tests

221 were documented for cardiovascular responses. With relatively small differences in the

222 number of throws and metabolic changes reflected by blood lactate levels, post-exercise HR1

223 and HR2 values were significantly greater after seoi-nage throws.

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229 Table 2. Comparison of total number of throws and SJFT Index in tests performed according

230 to the classic SJFT formula using training partners and grappling dummies

Zmienne	**X**	**SD**	**x_1-x_2**	**Z**	**p**
SJFT –P(Tt)	27,1	1,2	0,4	0,31	0,75
SJFT – M(Tt)	27,3	1,6			
SJFT –P(If)	12,41	1,02	0,39	1,81	0,07
SJFT – M(If)	12,02	1,28			

231 If- Index of fitness, Tt-Total throws, SJFT- P- Special Judo Fitness Test person, SJFT- M-

232 Special Judo Fitness Test grappling dummy, Wilcoxion signed-rank test

233 As shown in Table 2, there were no statistically significant differences between the number of

234 seoi-nage throws (performed with a partner) and o-goshi throws (performed on a dummy) and

235 those performed according to the classic SJFT formula. There were also no statistically

236 significant differences in Index of fitness values measured after the completion of the two

237 tests presented (Table 2).

238
239 Table 3. Relationships between SJFT and SFTCS, in terms of the number of throws and Index

240 of fitness, and relationships between the first and second trials of the SFTCS test in terms of **a**

241 total number of throws and Index of SJFT.

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Variables	r/R	p
SJFT(Tt) and SFTCS I	**0.85**	**<0.001**
SJFT(Tt) and the SFTCS II	**0.87**	**<0.001**
SJFT (If) and SFTCS I	**0.93**	**<0.001**
SJFT (If) and SFTCS II	**0.82**	**<0.001**
SFTCS I and SFTCS II	**0.81**	**<0.001**
SFTCS Index I and SFTCS Index II	**0.87**	**<0,001**

r-Pearson's coefficient, R - Spearman rank correlation coefficient, p - testing probability, numbers in bold denote statistical significance

As shown in Table 3, the correlations between the SJFT and SFTCS test are very high and statistically significant. Similarly, the correlations between the SFTCS test taken at the beginning and at the end of the period studied are very high and statistically significant.

Table 4. Coefficient of variation (CV%) of the number of throws, index of special fitness (Index), and mean heart rate calculated from two time points after the tests (MHR)

Test	**Total throws**	**Index of fitness**	**MHR**
SFTCS	8.45%	11.67%	3.1%
SJFT	5.30%	6.54%	2.9%

As can be seen from Table 4, greater variability in the number of throws and Index of fitness between terms was observed for the SFTCS test.

Discussion

The results indicate that the SFTCS test proposed by the authors can be used as an alternative to the SJFT test. It was demonstrated that there were no differences between the number of seoi- nage throws (performed with a partner) and o-goshi throws (performed on a dummy) and those performed according to the classic SJFT formula. No differences in Index of fitness values were observed either. Such results demonstrate the validity of the SFTCS test. An additional confirmation of the thesis of the validity of the mentioned test are high correlations between the results of the SFTCS test and the results in the SJFT test, obtained both by judo and ju-jitsu athletes. The reliability (repeatability) of the test is evidenced by high correlations between SFTCS test performed at the beginning and at the end of the research period.

Greater variability in the parameters of both techniques between the two test dates was found for the SFTCS test. This fact does not translate into the inferior reliability of this test compared to the SJFT, but it is due to the significant improvement in the technical performance of the new task after the 2-week period. It should be noted that the precondition for the usability of the test-retest reliability procedure is to master the technique in such a way, that the so-called motor-learning effect, which occurs in the short-term period of adaptation to previously unused exercise tests, can be excluded.

The classification and pattern of physiological mechanisms of the body during the authors' SFTCS test is consistent with the course of the fight in judo and ju-jitsu (33,59). The highest contribution of anaerobic processes in meeting the energy demands is observed at the initial stage of the exercise before aerobic transitions are activated in mitochondria, whereas the activity of the circulatory and respiratory systems reaches the level that corresponds to the oxygen demand (60). This is a period of oxygen debt. Therefore, this exercise can be qualified as the high-intensity anaerobic glycolytic-lactic exercise that determines the level of anaerobic endurance of the athlete studied.

A significant improvement of the o-goshi test results following a 2-week training is probably due to the improved technique of performing a new exercise test rather than a great improvement of fitness as indicated by the seoi-nage test parameters. It is worth looking for the reasons why the cardiovascular response and the rate of anaerobic glycolysis are higher after seoi-nage despite a similar number of throws in both tests. Considering the qualitative evaluation of the work performed by the thrower, it seems that a single seoi-nage throw requires the development of more power and energy expenditure. The total work done during the performance of the seoi-nage throw has two components: energy expenditure expressed in (Joul), potential energy expressed by the formula Ep=m*G*h, where m is the mass of the athlete thrown, G=9.81kg*m/(second)2, and h is vertical shift of body mass center of uke. The

291 second component of energy expenditure is the uke rotation energy as given by the formula:
292 Er=0.5*I* (ω)2 where I is the moment of inertia of the human body and ω is the rotational
293 speed expressed in radians. Also in this case, the Er value is expressed in Joules and is greater
294 for the greater mass of the uke and faster performance of the throw.

295 In our study, the o-goshi throwing test elicits lower physiological responses, i.e., post-
296 exercise lactate levels and lower heart rate compared to the time-equivalent seoi-nage
297 throwing test. This is likely to be due to the lower mechanical work or energy expenditure in
298 the o-goshi test using a light (33 kg) dummy for all weight classes. In this case, with a single
299 throw, the work required to verticalize the dummy is E=33kg*1.11m* G = 359 Joul. The
300 second component is the work performed by the tori when inclining the body, and then the
301 rotational energy of the dummy that can be ignored in the overall balance. A set of o-goshi
302 throws is performed directly one after another with minimal rests, and therefore the effort can
303 be considered continuous and uniform. Seoi-nage throws are more energy-intensive and are
304 separated by an average of 3-second breaks, which qualifies the overall test as high-intensity
305 interval exercise.

306 Since specific judo fitness has not been studied in the literature using 1-minute (2
307 times 30s) sets of throws, post-training changes in fitness in judokas recorded by other
308 researchers are difficult to compare with those obtained in our study. This applies to both
309 seoi-nage and o-goshi throws. Regarding changes in physical fitness after training periods, the
310 literature presents examples of positive effects. Post-training improvements in field test
311 performance have been reported in many studies(18,39,61). After six weeks of training, a
312 relative increase of 3.7% in total throws was reported in the SJFT test (34). In this study, the
313 mean total throws in sets B and C lasting 60 seconds in total was 20.9 before the training and
314 21.7 after training, which is very similar to the results obtained in our study for 1-minute
315 exercise. According to Sterkowicz et al. (34), the improvements in post-training performance

316 in the SJFT are more likely to be due to neuromuscular adaptation and improvement in seoi-
317 nage technique (especially the speed of the grip-and-throw sequence) than changes in the
318 cardiorespiratory system. On the other hand, in addition to the effect of good technique, the
319 performance level significantly depends on anaerobic power and aerobic capacity, as
320 evidenced by positive correlation coefficients between total throws and indices of laboratory
321 tests (42). The data on total throws in the SJFT allowed for developing fitness standards for
322 female (36) and male athletes (37), taking into account age categories, that classify the
323 subjects' fitness as poor to excellent. However, based on total throws in comparative
324 observations conducted by many authors, it is apparent that one of the key elements
325 determining the number of throws in SJFT may be weight-dependent agility (agility). The
326 level of this trait determines the speed of the run with sequential changing of run direction.
327 Studies have shown that body mass (38) and agility (39) are independent predictors of total
328 throws in SJFT.

329 It is worth emphasizing that the studies cited above overlook some important
330 determinants affecting the level of SJFT performance. One of them is the forced weight
331 reduction preceding the competition. The introduction of a restrictive diet (2192 Kcal/day) for
332 a group of athletes with a mean body weight of 75.9 kg resulted in a decreased body weight to
333 a mean value of 72.7 kg and a statistically significant deterioration in mean total throws (26.3
334 vs. 31) and greater post-exercise cardiovascular responses (62). In our study, the mean post-
335 training decreased body weight by less than 1 kg can be neglected as a factor affecting
336 physical fitness.

337 In the light of our findings and those documented by other authors, it can be observed
338 that throwing tests using the conventional SJFT test (15+30+30) and its modification (60 s)
339 and the o-goshi technique using a dummy (60s) performed in the field conditions can be
340 useful for the assessment of the general level of special physical fitness. Furthermore, throws

with a dummy can be recommended in training because they eliminate health risks in judokas. However, athletes should be provided with access to dummies of various weights. In the absence of a dummy, it is possible to return to the sparring or test with the involvement of sparring partners (ukes). Bearing this in mind, it is advisable not to use such techniques with tired athletes, because during or immediately after intensive exercise, greater angular accelerations are observed in ukes, consequently leading to the accumulation of micro-traumas that are harmful to the central nervous system (63).

Conclusions

The specific movements performed during the judo fight justify the introduction of tests based on throws to the examination of special fitness. The use of the o-goshi throw and the introduction of grappling dummies does not change the diagnostic value of the SJFT test. The classification and pattern of physiological mechanisms of the body during the authors' special fitness test (SFTCS) is consistent with the course of the fight in judo and ju-jitsu. The proposed SFTCS test offers an alternative to the SJFT test and represents a selective, valid, reliable, and simple diagnostic tool for testing the special fitness of judo and ju-jitsu athletes. A specific throwing test using a dummy can offer a convenient tool for both the assessment of the athlete's physical fitness and in throwing training, as it does not require a partner and does not pose a risk of injury to the athlete.

Practical implications.

The special fitness test (SFTCS) proposed in this study can be a tool for selection and interpretation of athletes' performance in both judo and ju-jitsu because it offers a reliable, valid, and user-friendly research tool. The proposed test can be used in a safe way and without special equipment for the comprehensive assessment of the level of preparation used for the

comprehensive assessment of the level of preparation in terms of special fitness in judo and ju-jitsu.

Declarations

Abbreviations: SJFT- P- Special Judo Fitness Test person, SJFT- M- Special Judo Fitness Test grappling dummy

Ethics approval and consent to participate: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Regional Medical Board in Krakow (approval No. 287/KBL/OIL/2020). Informed consent was obtained from all subjects involved in the study.

Consent for publication: Not Applicable

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