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Performance of novice's judokas in physical field tests after a block of unloaded muscle strengthening

Jean-Paul KOUASSI [1, 2, 3, *], Stève Marjelin Donan FALOLA [2, 3], Coffi QUENUM [2, 3], Brigitte AFFIDEHOME TONON [2], Léonce LINTA [2, 3], N'Guessan KOUAME [1] and Antoine Némé TAKO [4]

[1] *Laboratory of Human Movement Sciences, Development and Well-Being, National Institute of Youth and Sports (INJS), Abidjan, Côte d'Ivoire.*
[2] *Sport, Health and Evaluation Research Unit, National Institute of Youth, Physical Education and Sport (INJEPS), University of Abomey-Calavi, Porto-Novo, Benin.*
[3] *Centre of Expertise and Training for Sports Professionals, 12th district of Cotonou (Benin).*
[4] *Félix Houphouët-Boigny University (UFHB), Cocody Abidjan, Côte d'Ivoire.*

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Abstract

Objective: In Judo, many beginners participate to competitions without being in good physical condition despite the risks involved. The objective of this study was to measure the changes in physical performance induced by an unloaded muscle strengthening (MS) program in novice judoka.

Method: 24 male judoka students, all at maximum blue belt level (21.8 ± 2.1 years; 171.7 ± 7.9 cm; 70.1 ± 8.6 kg), were randomly divided into two groups. The experimental group (EG), undergoing a 6-week block of MS, while the control (CG), which followed the usual technical training. The subjects' performance on counter movement jump, Yo-Yo IRT2 and Special Judo Fitness Test (SJFT) were measured before, three weeks after and just at the end of the training period.
Results: After 6 weeks, the SJFT index decreased by 14.7% ($p = 0.004$), while the $\dot{V}O_2$max, reactivity index and left hand grip strength increased by 2.3% ($p = 0.01$), 12.14% ($p = 0.01$) and 8.32% ($p = 0.006$) respectively in the EG group. In the CG group, non-significant differences were observed in all performances.

Conclusion: The MS program enhanced the general and specific physical performance of novice judokas over a period of six week. In order to facilitate access to high performance, it should be systematically integrated into the physical preparation of young beginner judokas.

Key words: Judo; Strength Training; Field Test; Special Judo Fitness Test; Sub-Saharan Africa

1. Introduction

Judo is an intermittent combat sport characterized by actions performed at very high intensity, both in training and in competition, using a wide range of techniques [1,2]. Judokas must therefore have sufficient physical resources to throw their opponents or immobilise them on their back [3]. Physical preparation is therefore of paramount importance and must take into account the particularities of judo, so that practitioners can achieve the levels of performance required in competition [4]. Adequate physical preparation not only improves the physical capabilities of judoka, but also reduces the risk of injury in competition, thereby increasing the chances of success [2].

* Corresponding author: Jean-Paul KOUASSI

This preparation should integrate the main physiological and physical factors that influence judo performance, in particular speed, endurance, muscular strength and their various components [5, 6]. It should also be integrated into training sessions through specific muscle strengthening sequences aimed at developing the muscle's capacity to produce different types of force (maximal, explosive, plyometric, etc.) without inducing muscle hypertrophy [7].

In sub-Saharan Africa, it has been shown that coaches and athletes have limited knowledge about muscle strengthening and its integration into training sessions [7]. Yet in these southern countries where practice conditions are difficult [8], it would be beneficial for novice judokas (rank below brown belt) to integrate muscle strengthening into training sessions in order to optimize their physical preparation, by simultaneously improving physical, energetic and technical-tactical capacities [2]. In these sub-Saharan countries, novice practitioners, despite the potential risk of injury, enter competitions, even though their physical preparation is often inadequate or unsuited to the demands of judo. Despite the crucial importance of muscle strengthening for judoka, there are very few studies on the effects of a muscle strengthening program integrated into training sessions for novice judokas in sub-Saharan Africa. The present study aims to compare the performance of novice judokas in field physical tests (SJFT), after a specific muscle strengthening block or usual technical training.

2. Materials and methods

2.1. Participants

Two groups of judokas were formed, the Experimental Group (EG) and the Control Group (CG). Only the EG was subjected to the muscle strengthening microblock. The intervention was carried out in accordance with the recommendations stipulated in the Declaration of Helsinki (1964) [9], after approval by the Sectoral Scientific Committee of the National Institute of Youth, Physical Education and Sport (INJEPS). Written informed consent from each student was required and obtained.

The sample consisted of 24 male judoka students from the 47 available at INJEPS, who met the following inclusion criteria (judoka under 25 years old; federal license valid for the 2023-2024 season; green or blue belt and at least two competitive seasons). Judokas with less than 6 hours of weekly training were not included in the sample. Judokas who were sick or absent from a measurement session, as well as those who were absent from three of the 18 scheduled training sessions, were excluded from the study.

Participants in the -60 kg, -66 kg and -73 kg weight categories were randomly divided into two groups: an experimental group (EG) was given an unloaded muscle-strengthening program as a partial replacement for their usual technical training, while the control group (CG) continued with their usual technical training.

2.2. Experimental Approach

This was a controlled intervention study, conducted using a 2 x 3 design, with two groups of young male judoka students undergoing two distinct 6-week training program: a specific muscle-strengthening mini-block and a routine technical training program. Performance on physical tests, including the Special Judo Fitness Test, was measured in all participants at the beginning, midway (3 weeks), and end of the 6-week training period.

3. Measurement

Height and body mass were measured to the nearest 0.1 cm and 100 g, respectively, using a wall-mounted stadiometer and an automatic scale (Xiangshian, China). The body mass index (BMI) was calculated using the formula BMI: BM/H^2 where BM = body mass in kg and H = height in meters. Rectal temperature (Tr) and resting heart rate (RHr), expressed in degrees Celsius (°C) and beats per minute (bpm) respectively, were measured using MT 101R automatic thermometers (Hangzhou Sejoy, China) and an AND UA 767 electronic blood pressure monitor (A&D Medical, Australia), respectively. The countermovement jump tests without arms and the jump-reactivity tests were performed using the OptoJump Next system (Microgate, Italy), aiming each time for maximum height, as well as minimal ground contact time. Hand grip strength was measured with an electronic Grip D dynamometer (Takey, Japan) [10], and $\dot{V}O_2max$ was indirectly estimated from the results of the Yo-Yo Intermittent Recovery Test 2 [11], using the formula: $\dot{V}O_2max$ (mL/min/kg) = IRT2 distance covered (m) x 0.0136 + 45.3.

The SJFT was performed in groups of three judokas of the same weight category, with one Tori and two *Uke* [11]. Tori performed a shuttle run by throwing each *Uke* in turn during three respective periods of 15 s, 30 s, and 30 s with *Ippon soe nage*. The *Uke* were 6 meters apart from each other, and Tori was in the middle, 3 meters from each *Uke*. The heart rate was immediately recorded at the end and one minute after the test. The SJFT index (ISJFT), which allowed for the determination of the level of specific abilities of judokas by referring to the ISJFT classification table, was calculated using the following equation: ISJFT = (heart rate immediately after the exercise + heart rate one minute after the test) / total number of throws [12].

4. Training Programs

The training program consisted of a micro-block of specific muscle strengthening for the EG judokas and a standard technical training program for the CG judokas (Figure 1).

4.1. The Classical Judo Component

This component consisted of *Gokyo* learning exercises, exercises to improve the guard (*Kumi-kata*), and standing and ground combat (*randori*). The training sessions lasted an average of two hours. Each session included six different components: 1) the salute and gripping (5 min), 2) the warm-up (20 min), 3) technical-tactical study (40 min), 4) *Randori* or free combat (40 min), 5) relaxation and cooling down (10 min), and 6) the salute and regaining control (5 min). The actual working time was for the warm-up, the technical-tactical study and the Randoris (100 min). This typical session was carried out by the CG.

Unlike the EG practice, the 10-minute general warm-up was followed by a core strengthening phase of similar duration. A 20-minute muscle strengthening sequence with judo exercises was then performed, followed by 20 minutes of technical-tactical study while CG performed 40 minutes of technical-tactical study. The other parts of the training were identical.

4.2. Specific Muscle Strengthening Block

The objective of the 6-week microblock (structured into three two-week miniblocks) was to improve strength-speed (explosiveness) and specific endurance (Table 1).

- The energy objectives of miniblock 1 were to optimize pure speed (ATP-CP energy source) and maximal aerobic power (MAP), which were worked on in four and two sessions respectively out of the six planned, corresponding to 60% and 40% of the training time. On the technical-tactical level, this first mini-block aimed at the technical study of *Ne-waza* ground combat. *Osaekomi-waza* (immobilizations) thus filled 60% of the time, i.e. 4 sessions, and *Shimé-waza* (strangleholds) 40% of the time, i.e. 2 sessions (Table-1).

- Miniblock 2 focused on energy, on improving pure speed (ATP-CP energy source) for 2 sessions, i.e. 40% of the working time, and on maximum aerobic power (MAP) for 4 sessions, i.e. 60% of the working time. On the muscular level, speed-strength and plyometric strength occupied 2 and 4 sessions, i.e. 40 and 60% of the time, respectively. On the technical-tactical level, the study of projection techniques or *Nage-waza* filled this section. Thus, 40% of the time was devoted to *Te-waza*, 40% of the time to *Koshi-waza* and 20% of the time to *Ashi-waza* (Table 1).

- Mini-block 3 was energetically focused on improving pure speed (ATP-CP energy source) for two sessions, or 40% of the time, and maximal aerobic power (MAP) for 60% of the time, or four sessions. Muscularly, improving strength-speed took up 60% of the time, and improving specific strength-endurance took up 40% of the time, or two sessions. Technically and tactically, *Ne-waza* and *Nage-waza* each occupied 50% of the time, with standing-to-ground connections (Table-1).

Table 1 Objectives of the micro-training blocks

	Physiological objectives	**Number of sessions (%)**	**Muscular objectives**	**Number of sessions (%)**	**Technical and tactical objectives**	**Total number of sessions (%)**
Microbloc 1	- Energy source ATP-CP	4 (60%)	- Isometric strength	4 (60%)	- Improving des *Ne-waza*	6 (100%)
	- MAP	2 (40%)	- Force-speed	2 (40%)		
Microbloc 2	- Energy source ATP-CP	2 (40%)	- Force-speed	2 (40%)	- Improving *Nage-waza*	6 (100%)

	- MAP	4 (60%)	- Plyometric strength	6 (60%)		
Microbloc 3	- Energy source ATP-CP	2 (40%)	- Force-speed	4 (60%)	- Improving des *Nage-waza* et *Ne-waza* - standing-to-ground connection	6 (100%)
	- MAP	6 (60%)	- Specific endurance	2 (40%)		

Energy source ATP-CP : Pure speed; MAP : Maximum aerobic power

4.3. The Core Section

This section was primarily composed of isometric contraction exercises. The core exercises were primarily aimed at improving body balance, both in static positions and during movement, and promoting momentum transmission (Figure 1). They were performed in 5-minute (min) sets. Each set consisted of 5-second (s) repetitions followed by recovery periods of the same duration. Following the core workouts, specific muscle strengthening exercises were performed using exercises based on judo techniques.

4.4. Judo-Specific Muscle Strengthening Execution Model

Judo-specific muscle strengthening aimed to improve execution speed and explosiveness in technical movements through judo-specific exercises. The methodology employed was based on the use of concentric, eccentric, and plyometric contractions, with and without partner resistance (Figure 1).

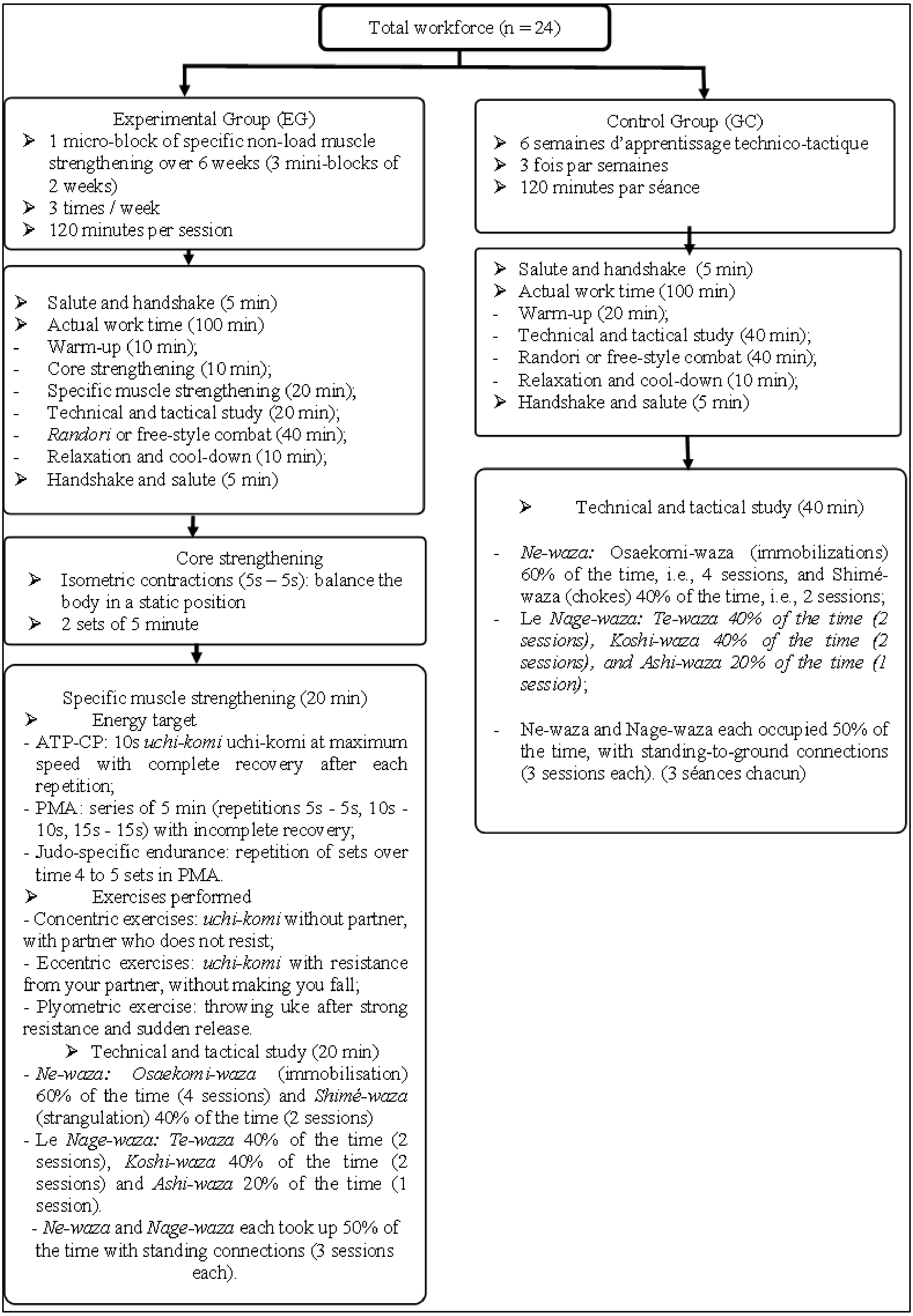

Figure 1 Micro-block of muscle strengthening protocol and technical-tactical training

4.5. Description of Judo-Specific Muscle Strengthening Exercises

- The concentric exercises consisted of *Uchi-komi* (repetition of the throwing gesture) on the special *Tokui-waza* (the athlete's preferred gesture) without a partner, with a partner (the partner does not resist), and *Nagé-komi*. These exercises were performed statically and then while moving.
- The eccentric exercises consisted of performing the same *Uchi-komi* exercise with the partner resisting without causing the athlete to fall (statically or while moving). The aim of the moving exercise is to increase the speed of execution of the movement and to get closer to the real form of combat.
- The plyometric exercises consisted of unstumping or projecting the partner (Uke) after strong resistance and then a sudden release of the latter, thus allowing a strong and rapid movement of *Tori*. This mode of work favored an eccentric contraction, immediately followed by a concentric contraction of the muscles used for the projection. This work was carried out on the spot and while moving (Figure 1).

4.6. Objective of Muscle Strengthening Using Judo Exercises and Execution Method

Muscle strengthening using judo exercises aimed energetically at maximal aerobic power (MAP) as the primary objective (Figure 1). The second objective was ATP-CP capacity. The final objective was to achieve judo-specific endurance. In MAP, the exercises were performed with repetitions designed according to the 6 s - 6 s, 10 s - 10 s, or 15 s - 15 s model, i.e., 6 s of effort and 6 s of recovery or 10 s of effort and 10 s of recovery in sets of 5 min maximum. The athletes' recovery was incomplete and active. In the exercises designed to develop ATP-CP capacity, the same work sequences were performed, but this time the athletes' recovery was complete and passive, so the judokas only resumed activity once the cardiovascular parameters returned to their resting values (approximately 70 bpm/min).

4.7. Statistical Analysis

The data were processed using Statistica software (version 10). The normal distribution of variables was verified using the Kolmogorov Smirnov test. The results were presented as means. The ANOVA test was used to search for interactions by time and group (Time x Group interaction). For normally distributed variables, the ANOVA test and Tukey's post hoc test were performed. For variables with non-normal distributions, the Friedman test and the Wilcoxon signed-rank test were performed. Comparisons between groups were made using the Student t-test for variables with normal distributions and the Mann Whitney U test for variables with non-normal distributions. The significance level for statistical tests was set at $p < 0.05$.

5. Results

The assessment of physical and physiological changes induced by a specific muscle strengthening (RMS) program in novice judokas required consideration of the parameters presented in both groups (Table 2).

Table 2 General characteristics of the beginner judokas studied (n = 24).

	EG (n = 11) m ± s	**CG (n = 13)m ± s**
Age (years)	21.9 ± 1.8	21.77 ± 2.3
Height (cm)	170.0 ± 7.1	173.2 ± 8.5
Body mass (kg)	70.4 ± 7.4	69.8 ± 9.5
Body Mass Index (kg/m^2)	24.2 ± 1.8	23.3 ± 2.9
TTW (hours)	6.0 ± 1.0	6.0 ± 1.0
$\dot{V}O_2$max (mL/min/kg)	50.3 ± 0.6	51.1 ± 1.4
Resting heart rate (bpm)	62 ± 6	64 ± 6

Numbers in boxes represent mean values ± standard deviations; TTW: training time per week; $\dot{V}O2$max: maximal oxygen consumption, estimated from Yo-Yo IRT2 results; bpm: beats per minute.

The results revealed significant improvements in the number of throws, the Special Judo Fitness Test Index (ISJFT), the distance covered in the yo-yo-IRT2, $\dot{V}O_2$max, and left-hand grip strength (Table 3).

Table 3 $\dot{V}O_2max$ and Performance in SJFT, jump tests and grip strength (n = 24).

	EG			CG		
	M1	**M2**	**M3**	**M1**	**M2**	**M3**
Throws	21.9 ± 2.2	23.0 ± 2.2	24.2 ± 2.2*†	21.9 ± 2.5	21.3 ± 1.7	22.6 ± 1.8
SJFTI	15.4 ± 2.13	14.1 ± 1.8	13.3 ± 1.4*	15.7 ± 2.7	15.9 ± 1.6	14.7 ± 1.7‡
$\dot{V}O_2max$ (mL/min/kg)	50.3 ± 0.6	51.6 ± 1.8*	51.5 ± 1.3*	51.1 ± 1.4	51.9 ± 1.4	51.5 ± 1.5
RHGS (N)	540.7 ± 67.6	556.5 ± 57.8	577.4 ± 63.4	506.87 ± 61.2	527.7 ± 60.8	540.5 ± 54.9
LHGS (N)	517.5 ± 65.4	531.6 ± 52.3	560.5 ± 46.2**††	518.0 ± 75.3	501.2 ± 57.4	514.2 ± 58.4
CMJ (cm)	35.4 ± 4.8	35.8 ± 3.5	36.7± 3	36.3 ± 2.9	37.1 ± 3.6	34.6 ± 3.4*††
RI	1.0 ± 0.6	1.1± 0.5	1.2 ± 0.4*†	0.9 ± 0.4	0.8 ± 0.2	0.84 ± 0.21*

The values in the boxes represent the means (m) ± standard deviations (s); EG: Experimental group; CG: Control group; Throws: total number of throws performed during the SJFT test; $\dot{V}O_2max$: maximum oxygen consumption calculated from the results of the YO-YO IRT2; CMJ: height of the counter-movement jump without arms (cm); IR: reactivity index; GFRH: right-hand grip strength (Newton); GRLH: left-hand grip strength (Newton); *difference with M1, significant at p < 0.05; †difference with M2, significant at p < 0.05; ‡ difference with GE, significant at p < 0.05; ††difference with M2, significant at p < 0.01. M1: measurement before the training program; M2: measurement after three weeks of training; M3: measurement at the end of the training program (after 6 weeks).

In the EG , at the end of the microblock, only the left hand grip strength significantly increased between measurements taken before the start of the microblock (M1) and at the end of six weeks (M3) (8.32%; p = 0.006), and then between measurements taken after three weeks of training (M2) and at the end of six weeks (M3) (p = 0.003). In the CG, the variation in grip strength of each hand was not significant (p = 0.3).

In the EG, a non-significant increase in jump height (3.72%) was recorded (Table 3), while in the CG, significant decreases between measurements M1 and M3 (-4.64%; p = 0.03) and between measurements M2 and M3 (p = 0.008) were observed. The intergroup test revealed a non-significant difference. A significant improvement of 12.14% (p = 0.01) in the reactivity index was recorded in the EG (Table 3) between measurements M3 and M2, while the CG presented, on the contrary, a significant decrease of 14.28% (p = 0.02) between measurements M1 and M3.

In the experimental group (EG), the number of throws performed during the SJFT test increased significantly (11.5%; p = 0.02) between measurements M1 and M3 (Table 3). This increase was also significant between measurements M2 and M3 (p = 0.01). The SJFT index (ISJFT) decreased regularly between measurements M1 and M2 (- 8.4%; p = 0.02) and then between M1 and M3 (-14.7%; p = 0.004). Between measurements M1 and M3, $\dot{V}O_2max$ improved by 2.3% (p = 0.01). In the control group (CG), the changes in the number of throws and the SJFT index were not significant (p = 0.09). The same was true for $\dot{V}O_2max$ (p = 0.07).

6. Discussion

This study was based on the hypothesis that a judo-specific muscle strengthening microblock improves physical abilities, performance on physical tests, and the SJFT in novice judoka students. Results revealed that performance on the Special Judo Fitness Test, $\dot{V}O_2max$, reactivity index, and left-hand grip strength improved after six weeks of specific muscle strengthening. Six weeks of training, with three sessions per week, appears to be sufficient time to observe changes in athletes, especially since some studies have recorded changes in physical abilities after a five-week training program [13, 14]. The results obtained can be considered reliable, since measures were taken to ensure compliance with methodological requirements in training and data collection. The results are also valid for novice judokas, since the sample consisted only of novice judokas regularly participating in the Benin National Judo Championship and representing the backbone of the university team of the National Institute of Youth, Physical Education and Sport (INJEPS).

In this study, where all judokas had the right hand as their dominant hand, the grip strength of the left (non-dominant) hand significantly increased at the end of the muscle strengthening program, however the grip strength of the dominant hand remained higher than that of the non-dominant hand. In judo, the hands play an important role in the grip of the Kumi kata [2].

The non-dominant hand also participates in the grasp of the *Kumi kata* and its action is fundamental in the imbalance of the opponent [15]. The sustained and regular training has strengthened the muscular capacities of both hands, particularly that of the non-dominant hand, the increase of which has been statistically significant. Indeed, both hands are used in the same way during the fight, where half of the time is devoted to the battle of *Kumi-kata* [16, 15], one of the essential factors of the fight [2].

The six-week muscle strengthening program combined with technical-tactical training sessions improved the muscular performance of the novice judokas in the study through improvements in jump height and reactivity index. The reactivity index reflects the improvement in the explosiveness of these athletes. Indeed, the muscle strengthening program consisting of plyometric exercises, combined with core strengthening exercises, improved the muscular and energetic capacities of the judokas. One of these improvements resulted in an increase in the reactivity index of the pelvic limbs. The plyometric exercises integrated into the program and combined with core strengthening exercises produced a beneficial effect on the reactivity of the pelvic limb muscles [18].

The good level of core strength is also correlated with athletic performance [19]. The stretching-shortening cycle used during plyometrics allows the muscle to store energy, then release it to produce energy, thus improving the efficiency of the movement [18]. Exercises performed in short sequences (5s - 5s) at maximum aerobic power (MAP) and during core strength induced an increase in the number of muscle fibers recruited during the movement. This allowed more power to be generated, thereby improving explosiveness in the novice judokas studied. This explosiveness is essential for attack and defense movements, which must be brief, fast and powerful in order to surprise the opponent or avoid an unexpected attack [2, 3].

A similar increase in jump height and execution speed was observed after a period of physical preparation in young judokas outside the African continent [20, 21]. It is therefore important to integrate muscle strengthening early in the preparation of combat sports athletes to improve their physical, muscular, and energetic capacities.

The muscular improvements observed in the judokas in the study were also energetic. Exercises performed at maximum aerobic power improved aerobic capacities. The MAP exercises were performed in an intermittent and explosive mode. These exercises improved muscle oxidative capacities, as well as ATP-CP capacities and anaerobic lactic capacity.

It is well known that all of these energetic capacities contribute significantly to optimizing judo performance [4], thus contributing to high-level performance.

The combination of all these factors led to an improvement in SJFT performance, with an increase in the number of throws. This improvement is explained by the combined effect of muscle strengthening (plyometrics and core strengthening), technical improvement, and physiological adaptation. Core strengthening improved proprioception, kinesthetic sensation, and postural alignment. The technical improvement facilitated more fluid and easy execution of techniques. As for the energy improvement, it allowed athletes to better resist muscle fatigue [4], especially during the final series of the test. This improvement in SJFT performance resulted in a significant decrease in the SJFT index. The performance achieved by the athletes in the study is close to that recorded in the United States among 12- to 13-year-old judokas, who achieved a significant decrease in ISJFT (-5.9%), after 4 weeks of training [20]. It should be noted that ISJFT experienced a more significant decrease in the present study (-14.7% vs. -5.9%). This more pronounced decrease can be explained by the fact that the young athletes (12- to 13-year-olds) studied in the United States [20] were still growing. They therefore do not yet have significant muscle mass and sufficiently developed buffer systems [22] to support a training load similar to that imposed on seniors in the present study. However, the ISJFT observed in the present study is relatively low according to reference standards [11] and is well below the performances of high-level African judokas [23, 24]. The judokas in the present study therefore still have room for improvement to achieve the performances of high-level athletes in the African elite. The weakness of the ISJFT in the present study can be explained by the low level of judo practice in sub-Saharan countries, the absence of strong rivalries between athletes due to the lack of high-level competitions, the difficult material and practice conditions [8, 25], the lack of awareness of the importance of muscle strengthening [7] and the non-integration of the SJFT into training as a relevant tool for assessing the physical condition of judokas, particularly among beginners.

During the present study, muscular and energetic improvements favored the increase in $\dot{V}O_2max$ which resulted in an improvement of the oxidative system in the novice judokas studied. The combination of maximal aerobic power and muscular power are therefore determinants of sporting success in a discipline like Judo [2]. Judokas with greater aerobic power have better performances in intense then intermittent activities especially in the last moments of the fight and have a better chance of winning the fight [4]. This is why the studies demonstrate that athletes at a high level of competition have a high $\dot{V}O_2max$, thus favoring the ability to maintain the succession of these actions and to recover between the numerous explosive actions [26]. This improvement in $\dot{V}O_2max$ also strongly contributed to the improvement in performance during the SJFT. It should be noted that this study did not, however, take into account the effect of the environment (heat and humidity) on the water status and performance of judokas.

7. Conclusion

This study was based on the hypothesis that a six-week microblock of specific muscle strengthening improves physical and physiological capacities and performance on the Special Judo Fitness Test in sub-Saharan novice judokas.

The results indicated that 1) specific strengthening improved the physical and physiological capacities of the novice judokas studied, namely the reactivity index, grip strength, jump height, and $\dot{V}O_2max$; 2) the improvement in physical and physiological capacities in these novices induced an increase in the number of throws on the SJFT and a decrease in the ISJFT; 3) aerobic capacity, particularly $\dot{V}O_2max$, is a determining parameter to consider when performing the SJFT in these novices.

The SJFT should be used as a training tool to assess judo-specific fitness and performance in beginners. Specific muscle strengthening should also be integrated into training sessions to optimize the fitness of novice judokas.

Future studies in these novice judokas, who perform in a hot and humid environment, would be relevant to assess the effect of dehydration on physical and muscular capacity, as well as on SJFT performance, and to determine the impact of this dehydration on aerobic and anaerobic power during the SJFT.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no competing interests.

Statement of informed consent

The intervention was approval by the Sectoral Scientific Committee of the National Institute of Youth, Physical Education and Sport (INJEPS) of Bénin. Written informed consent from each student was required and obtained before the intervention.

Authors' contributions

Jean-Paul KOUASSI [1-2-4], Stève FALOLA[3], Coffi QUENUM[2], Brigitte Affidehome[1-2- 5] TONON, Léonce SO LINTA[2-3], N'Guessan KOUAME [1-5], Antoine Némé TAKO[5]

1: Research project drafting; **2**: Carrying out the unloaded physical preparation program; **3**: Statistical analysis; **4**: Drafting the manuscript; **5**: manuscript proofreading.

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