JUMPING PERFORMANCES IN NATIONAL 2 WOMEN HANDBALL PLAYERS: EFFECT OF A 3-MONTH PLYOMETRIC TRAINING PROGRAM.

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This study investigates both jumping performances (in squat jump (SJ) and counter movement jump (CMJ)) and global lower limbs stiffness in women handball players and reports the effect of a 3-month plyometric training program (length: 45 min, once a week) on these parameters. Mean performance for SJ was 22.3±3.0 cm and for CMJ 29.3±4.1 cm. Lower limbs stiffness reached 21213±7510 $N.m^{-1}$. There was no correlation between the different parameters. Eight players followed the plyometric program but six were finally evaluated because of injuries. No change was observed for CMJ but lower limbs stiffness and SJ height tend to increase. This suggests that a unique 45-min plyometric training session once a week during three months may not be enough to enhance jumping capacities and lower limbs stiffness in women handball players.

KEY WORDS: adaptation, lower limbs, sport

INTRODUCTION: Handball is a strenuous contact sport that places emphasis on running, jumping, sprinting, arm throwing, hitting, blocking and pushing (Gorostiaga *et al*., 2006). These last years, the intensity of game changed with players running faster and longer, jumping higher and throwing stronger (Mangematin *et al*., 2010). Substantial strengths at upper and lower limbs levels are then developed during game to perform these actions. These parameters are important in women handball with, in addition, a significant part for the tactics. Based upon these observations, a new model of selection in women's handball focusing on different motor abilities like psychomotor speed (hand-tapping, foot-tapping), psychomotor coordination, running speed and medicine ball throw, for example, has been proposed (Srhoj *et al*., 2006). However, the skill of ball handling in the play can fully manifest only when other basic and specific motor abilities (speed of movement without ball, explosive strength of jump type) have reached a satisfactory level (Srhoj *et al*., 2006). Furthermore, it has been confirmed that, to improve ball-throwing velocity, explosive strength of both extremities, upper and lower limbs must be developed (Granados *et al*., 2007). Consequently, it appears that for women players, like for men players, a sufficient amount of physical work must be proposed, specifically concerning lower limbs capacities. Indeed, improving the lower limbs muscular capacities can be determinant in handball to earn efficiency on short efforts like accelerations, jumps, directions changes, throw. To have a high vertical jumping capacity can allow a player to throw the ball above the defender and score more easily. The only practice of handball is unfortunately not enough to develop those skills and a plyometric training program appears very interesting to improve explosive strength in lower limbs since it can improve explosive muscle strength and vertical jump height (Markovic *et al.*, 2010). As a result, the aim of our study is to characterise the jumping abilities in the amateur female handball and to test the influence of a plyometric training program on this population.

METHODS: Thirteen female handball players (reference group) playing in National 2 (Fourth division in France) participated to this study after presentation of the study design. All gave their informed consent. Study was conducted in accordance with the declaration of Helsinki.
Jumping performances were assessed using Optojump® (Microgate®, Bolzano, Italy). Results are presented as mean±SD.
Three different tests were performed successively: a squat jump (SJ) a counter movement jump (CMJ) and a hopping (multi-rebound) test to evaluate lower limbs stiffness (LLS).
For the SJ, players had to squat down and hold a knee position (approximately 90° knee angle) for a few seconds. On the experimenter's command, the participant was instructed to

jumps as high as possible. A trial was considered successful when there was no further squatting or counter movement before the execution of the jump.
For the CMJ, players were instructed to squat down as quickly as possible until they approximately reached the starting position of a squat jump, and then to jump as high as possible. For both tests, the best trial value was kept for analysis. The players performed no more than 6 trials for each test. A minimum of 1 min elapsed between two trials.
For the hopping test, participants had 2 trials separated by a 5-min passive recovery period. Each trial lasted 10s. Participants were asked to keep their knees as stiff as possible during test. The best test was recorded for the further analysis.
The calculation of stiffness (K, expressed in $N.m^{-1}$) for each impulse was accomplished using the formula developed by Dalleau & al. (2004):

$$K = \frac{M \times \pi(T_f + T_c)}{T_c{}^2\left(\frac{T_f+T_c}{\pi} - \frac{T_c}{4}\right)} \qquad (\text{in } N \times m^{-1})$$

where M represents the body mass of the subject, T_F et T_C (both in seconds) represents respectively the flight time and the contact time for each impulse.
Then the global value of LLS for the test is calculated by the average of value obtains for each impulse during test.
After this initial assessment, 8 players (plyometric group, PG) accepted to follow plyometric training in addition to their usual training. The workouts lasted 45 min once a week and occurred in the 45 min preceding the first handball training of each week. The PG followed the plyometric training during 3 months. Twelve plyometric workouts were finally performed. First part of the program consisted in initiation to plyometric exercises and was mainly composed of jumps in bleachers, lunge exercises and skipping rope exercises. After 2 weeks, the subjects showed good control of the movement and during the following 10 weeks, program moved mainly to bounding strides and step exercises (e.g. 3 series of 8 drop jumps from a 60cm-bench with 5 min of passive recovery between each series followed by jumps over hurdles (e.g. ten series of six jumps above hurdles with seven min of passive recovery)). No weight was used. Jumping performances were assessed again after this specific training period.

RESULTS: The anthropometric characteristics of the reference group were: 25±3years, 166±5.9cm, 62.4±6.4kg. They used to train three times per week for a global amount of 5h30 in addition to a match played during the weekend. The table 1 presents the individual results for jumping tests.

Table 1:
Individual performances in a group of women handball players for squat jump (SJ), counter movement jump (CMJ) and global lower limbs stiffness (Stiffness) values calculated from hopping test.

Players	Playing position	SJ (cm)	CMJ (cm)	Stiffness ($N.m^{-1}$)
1	Back	25.2	31.6	28520.12
2	Winger	24.5	32.4	15288.86
3	Winger	23.7	34.8	12033.45
4	Back	21.4	25.2	31603.57
5	Goal Keeper	27.3	30.9	23055.62
6	Pivot	23.2	30.2	13754.64
7	Winger	23.8	30.2	24261.45
8	Pivot	23.8	29.4	26736.33
9	Pivot	23.8	31.6	25809.92
10	Back	16.5	23.8	17357.12
11	Back	24.5	25.8	20451.57
12	Center Back	20.8	27.3	20828.96
13	Winger	24.5	28.7	22020.95

Mean jumping performance for SJ was 22.3±3.0 cm and for CMJ 29.3±4.1 cm. Mean global LLS was 21213±7510 $N.m^{-1}$. We did not observe any correlation between SJ and CMJ, SJ and LLS, CMJ and LLS.
The anthropometric characteristics of the plyometric group were: 22.6±1.0 years, 166±6.1cm, and 62.5±5.9kg. Eight players were initially included in the plyometric group but because of injuries only 6 participated to the final assessment. Considering the weak number of subjects in the plyometric group, we deliberately chose not to perform statistical analysis and will talk of tendency for the results.
Mean jumping performance for SJ seems to increase (24.1±1.8 cm vs. 22.3±3.0 cm) whereas plyometric training did not apparently affect CMJ jumping performances (29.4±3.3 cm vs. 29.3±4.2 cm). Mean lower limbs global stiffness tend to increase from 21213±7510 $N.m^{-1}$ to 23211±5003 $N.m^{-1}$ (Figure 1).

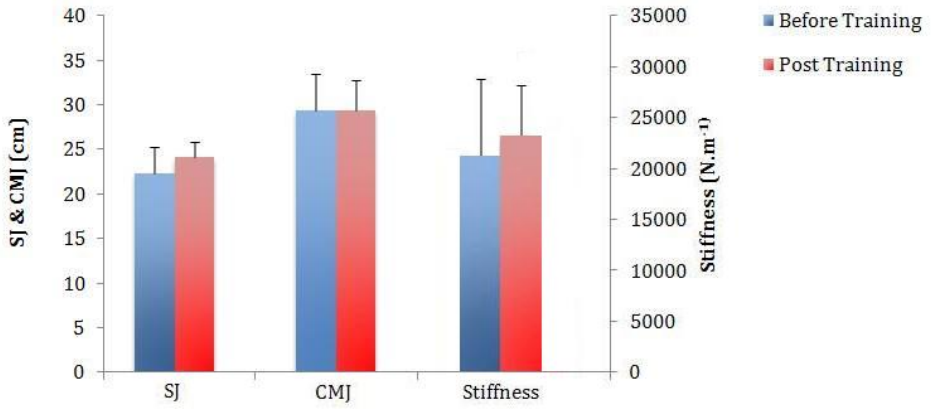

Figure 1: Squat jump (SJ), counter movement jump (CMJ) performances and global lower limbs stiffness (Stiffness) values calculated from hopping test before and after a plyometric training program in a group of 6 women handball players.

DISCUSSION: The main observation of our study is that 3 months of plyometric training did not induce a significant change in jumping performances in women handball players. There is few data concerning jumping performances for this population and to the best of our knowledge, we are the first to report SJ, CMJ and global LLS data for the same group of women handball players.
Jidovtseff *et al*. (2013) previously studied the impact of a resistance training program during a whole season in a group of amateur women handball players but reported only CMJ performance. (29±2cm). The values measured in our study are in the same range. We did not observe any correlation between SJ and CMJ, SJ and LLS, and CMJ and LLS in the reference group. This last result is not in accordance with the solicitation of the leg spring during the CMJ performance and contrasts with what has been described in male tennis players for example where leg stiffness was significantly correlated with CMJ jump height (Durand *et al*. 2010). The reason for such a discrepancy remains unclear and warrants further investigation. One hypothesis could be that the reference group included different kinds of players (goalkeepers, center back, winger, …). It is likely that these players developed different abilities in relation with the post played. Usually, the winger is a fast player, with good capacities for long jump whereas the center back is not as fast as the winger but more efficient in high jumps. Furthermore, it has been reported inferior motor abilities (standing high jump, standing long jump) but predominance in flexibility in handball goalkeepers compared to other players (Rogulj *et al*., 2005).
Jidovtseff *et al*. (2013) also did not report any change in CMJ performance after their training program. The resistance training they proposed included musculation exercise of a variety of muscular groups like pectoral muscle, triceps, trapezius muscle in addition to the calves, hamstring, quadriceps and gluteus maximus and could have lead to an improvement in jumping performance. However, one limitation of this study is the time allowed to the

resistance training since Jidovtseff et al. proposed only 30 min-long resistance training twice a week.
In the hope to obtain significant improvement of players' performance, we deliberately chose to focus on the development of lower limbs muscular capacities and proposed to a group of 8 women handball players a plyometric training in complement of their weekly trainings. A 45-min training session once a week appeared to us sufficient in this aim. The beneficial effects of plyometric training on SJ and CMJ performances and on global LLS has been previously proven (Markovic & Mikulic, 2010). The tendency observed in our group is an improvement in SJ performance and global LLS but no change in CMJ performance. The expectations were rather placed on the improvement in CMJ performances, but this was the case in only two subjects. In addition, four players increased and two decreased their global LLS following the plyometric training program. The reduced number of subjects during the final evaluation is a limit to our study. It will be necessary to pursue this investigation with the inclusion of other women handball players playing at the same, higher or lower levels to inform on the possible impact of this parameter and its development in women handball. Furthermore, the training program will be extended to another 3 months in order to check whether significant effects could be observed for such conditions.

CONCLUSION: Our study suggests that a unique 45-min plyometric training session once a week during 3 months may not be enough to enhance jumping capacities and lower limbs stiffness in national 2 women handball players. Due to its specificity, plyometric training, if not well applied, can enhance the risk of injury and the longer the length of the plyometric training session, the higher the risk. However, plyometric training is recognized a reference method to enhance lower limbs muscular capacities (Markovic & Mikulic, 2010). We recommend dedicating a specific training session to plyometric training with sufficient recovery to prevent players from injuries. To combine weight lifting to plyometric training alone could be a good option to enhance lower limbs performance in women handball players.

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