An analysis of jumping force manifestation profile in table tennis

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Abstract: The measurement of jumping forces allows to know and to quantify the physical needs of lower extremity in table tennis. This information could be a useful training planning method and a sport performance system control. The aim of this study was to assess the type and magnitude of different jumping forces in high level table tennis players. Five male players belonging to the Spanish national team participated in this study. Tests were performed according to the Bosco protocol: squat jump (SJ), Abalakov (ABK), squat jump with a progressive extra load of 25, 50, 75 and 100% of body weight (SJ_{PC}), reactive force during 15s (RRJ_{15}) and drop jumps (DJ) (from 20, 40, 60, 80 and 100 cm height, respectively). The analysis of total jumping capacity expressed as percentage reveals that table tennis players have a force profile of 16.3% for the contractile capacity, 64% for the instant ability to recruitment and synchronization, 7% of elastic capacity, 12.6% of arms contractile contribution. The assessment of all force manifestations, depending on the height reached, is useful for elaborating the force profile of a specific sport. The relation between different force values indicates that the tested players have a good force-speed relation. Fast muscle fibres prompt activation is essential in modern table tennis.

Keywords: jump force, strength profile, active manifestation, reactive manifestation, elasticity index.

1. INTRODUCTION

The search for elements that could improve athletes' performance and game action results is a matter of interest and research in many sport fields. Regarding table tennis, the assessment of the factors that may directly affect performance, has a special importance as a consequence of the game complexity, based on continuous middle and high intensity intermittent efforts, where the player has to react and choose the best technique in each situation in a short time [1-2].

Table tennis belongs to the racket sports group like badminton, squash or tennis, characterized by continuous changes of rhythm and intensity, with repeated fast actions of short duration during the whole match. During competition, table tennis players need to apply several physical skills such as speed, strength, cardiovascular endurance, agility, perceptive and taking decision skills, as a consequence of the continuous and changing situations of this dynamic game.

As a consequence of the new technical regulations applied in table tennis in the last years, there is a growing interest in evaluating the analysis of the metabolic responses of this racket sport. Recent studies [3-4] show that aerobic capacity is very important in this sport, being responsible for the player recovery during resting periods (i.e.: after each rally), as reported by Faccini et al. [5]. However, the anaerobic metabolism is of great importance in other game situations. There is no doubt that both capacities are essential in table tennis players [6-8].

However, few data are available regarding the different strength profiles of the lower extremities that may influence this sport [9-11].

Lower extremity movements are essential to achieve a right position that allows hitting the ball effectively [9]. The player needs to perform short and explosive movements, as a consequence of high-speed frequent changes of direction. Moreover, a high and constant state of muscle tension in the lower limbs is developed as a consequence of high uncertainty levels that depend on the possible reactions of the opponent.

The purpose of this study was to assess the different types of strength jump statements performed by male top-level table tennis players.

2. METHOD

Five male tennis table players, belonging to the Spanish national team, with an average age of 25 ± 5 years, took part in the study. We assessed the profile of two strength types, according to terminology established by Vittori [12]: active and reactive strength. The active strength has two manifestations: the maximal dynamic strength and the explosive strength. The reactive strength consists of the elastic-explosive strength and reflex-elastic-explosive strength.

To assess the strength values of each type of strength manifestation, the players were evaluated using the Bosco tests [13] consisting of: squat jump (SJ), counter-movement jump (CMJ), squat jump with progressive loads of 25, 50, 75 and 100% of body

weight (SJ_{PC}), countermovement jump with the arm swing (CMJA), drop jump (DJ) from five heights (20, 40, 60, 80 and 100 cm) and rebound jumps for 15 seconds (RRJ_{15}). The test was carried using a jump computer Newtest Powertimer® (Oulu, Finland), weight bars of 10 and 25 kg (Salter, Spain), plastic bars protection, five boxes (height: 20 cm), a scale and a stadiometer to measure weight and height (Seca 714, with a precision of 100 g and 1 mm, respectively). Players were evaluated after performing fifteen minutes of standard warm-up exercises. The values that were recorded and analysed corresponded to the average of each jump after three attempts.

With the aim of obtaining the profile of different strength types in table tennis, we applied the formulae proposed by Velez [16]:

Total Capacity (TC) = (SJ_{PC}) + (SJ- SJ_{PC}) + (CMJ-SJ) + (CMJA-CMJ) + (DJ-CMJA)

100% = (A%) + (B%) + (C%) + (D%) + (E%)

Where:

A% = Contractile Capacity (CC)
B% = Instantaneous Recruitment Capacity (IRC)
C% = Elastic Capacity (EC)
D% = Use Arms Capacity (UAC)
E% = Reflex Capacity (RC)

The different strength types analysed, with the description of the procedures that have been carried out in each jump, are described below.

2.1 Active strength manifestation

- Maximal strength dynamic manifestation ($SJ_{PC100\%}$). It could be measured when players were able to move the maximal load in a single movement without time limits.

- Explosive strength manifestation (SJ). It is a jump performed without previous countermovement, starting from a position with the knees at 90 degrees. With the hands on the hips, lower limbs must be extended during the jump. The legs contact the floor with front foot and extended knees. This test calculates the value of explosive strength, the synchronization skill and the instantaneous recruitment (SRC).

2.1 Reactive strength manifestation

- Elastic-explosive strength manifestation: countermovement jump (CMJ). Jump in countermovement with a fast legs flexion-extension. The flexion of the knees must reach 90 degrees. It differs from SJ due to the use of elastic energy. It measures the elastic capacity (EC). The difference between SJ and CMJ expressed as percentage corresponds to the elasticity index (EI) [13-15].

EI = [CMJ-SJ)/SJ]*100

- Rebound jump for 15 s (RRJ_{15}). The procedure is the same as CMJ, but keeping jumps during 15 s.

- Counter-movement jump with arms swing (CMJA). The same jump as in CMJ, but using arms. This jump allows measuring the elastic-explosive energy and arms using capacity (UAC%). The arms use index is the difference between high of CMJA and CMJ expressed as percentage.

Arms use = (CMJA-CMJ)/(CMJ)*100.

- Reflex elastic-explosive manifestation. Drop jump (DJ). It is calculated from different heights (DJ 20, DJ 40, DJ 60 and DJ 80 cm). The falls are carried out from the step without taking a run-up, and falling and rebounding are performed as faster as possible. It is used for measuring muscle elasticity, viscoelastic component, myotatic reflex, behavior of Golgi complex and reflex capacity (RC).

2.3 Others implications

- Strength-Velocity Index of Velez [16], related to SJ and SJ using loads. The formulae are:

S-V Index (100% BW) = (SJ-$SJ_{100\%PC}$)*100/SJ

S-V Index (50% BW) = (SJ-$SJ_{50\%PC}$)*100/SJ

- Bosco Index = $SJ_{100\%PC}$/SJ to determine the relationship between strength and velocity.

2.4 Statistical analysis

Data were statistically analyzed by means of descriptive analysis according to the following variables: weight, height, age and other variables associated with strength profile. Data are described as average values, standard deviation (SD), minimum and maximum values.

3. RESULTS

Table 1 Body Mass Index (BMI), weight (kg) and height (m) of the 5 players.

	Minimum	Maximum	Average	SD
BMI	21.54	27.87	24	2.46
Weight (kg)	65.2	96	77.24	12.03
Height (m)	1.74	1.87	1.79	0.06

Table 2 reports the results achieved with the Bosco test [13]. The average jump values of the reflex elastic-explosive manifestation were the highest values in the two types of expression: the CMJA with 38 cm and the DJ with 36 cm for DJ_{60}, and the lowest values were those corresponding to explosive strength ($SJ_{100\%}$: 8 cm). The elastic-explosive manifestation (CMJ) achieved an intermediate mean value (33.2 cm).

Table 2 Squat jump (SJ, $SJ_{25\%}$, $SJ_{50\%}$, $SJ_{75\%}$, $SJ_{100\%}$), countermovement jump (CMJ), countermovement jump with arm swing (CMJA), drop jump (DJ_{20}, DJ_{40}, DJ_{60}, DJ_{80}, DJ_{100}) values recorded in the test.

Jump (cm)	Minimum	Maximum	Average	SD
SJ	25	34	33.2	2.69
$SJ_{25\%}$	19	23	21.4	1.82
$SJ_{50\%}$	11	16	14.6	2.19
$SJ_{75\%}$	6	12	8.8	2.28
$SJ_{100\%}$	4	8	6.2	1.48
CMJ	29.67	37	33.2	2.7
CMJA	33	42.33	38	4.21
DJ_{20}	31	37	33	2.45
DJ_{40}	31	37	34.4	2.7
DJ_{60}	32	39	35.2	2.59
DJ_{80}	31	37	33.6	2.7
DJ_{100}	28	37	33.4	3.91

The height of the jumps achieved by each player and corresponding to the active strength manifestation is depicted in Figure 1. All subjects reached the highest height in the SJ with values varying between 34 cm (subject 4) and 25 cm (subject 5). The lowest values were achieved in $SJ_{100\%}$ with values varying between 4 and 8 cm.

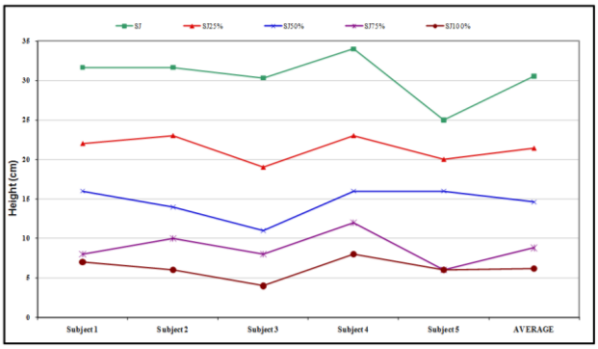

Fig. 1 Height values obtained in SJ, $SJ_{25\%}$, $SJ_{50\%}$, $SJ_{75\%}$ and $SJ_{100\%}$.

When the height values corresponding to CMJ, SJ and CMJA are compared, CMJA recorded the highest ones varying between 33.00 and 42.33 cm. The next jump in terms of height is the CMJ, with values included between 37.00 and 29.67 cm. Finally, the last jump is SJ (between 31.67 and 25.00 cm) (Figure 2).

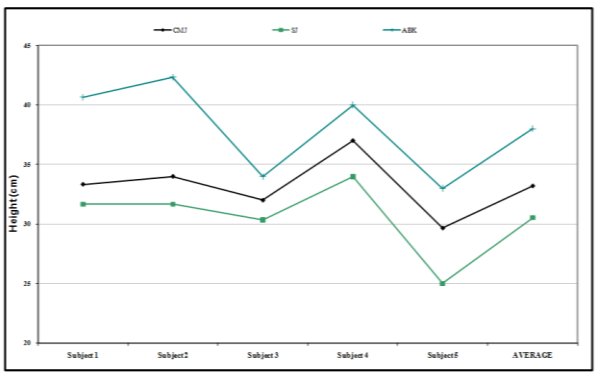

Fig. 2 Height values obtained in CMJ, SJ and CMJA.

When DJ data are analysed, differences between the tested subjects, according to their fall height, can be observed (Figure 3).

DJ average values, obtained from different height drops, were higher in DJ_{60} (35.2 cm) and lower in DJ_{20} (33 cm). However, maximum values were not the same for all subjects in the same DJ fall height.

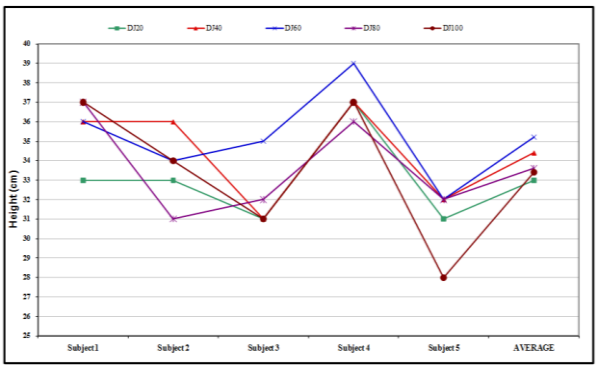

Fig. 3 Jumps height values in DJ from different fall height: DJ_{20}, DJ_{40}, DJ_{60}, DJ_{80} and DJ_{100}.

Table 3 summarizes the measurements used to determine the strength profile of the subjects [16], and the average values obtained for each tested skill. The active strength manifestations (recruitment capacity and contractile capacity) are 80.04% of the total. This value is higher than that of reactive manifestations (elastic capacity, use arms capacity and reflex component). Recruitment component recorded the highest mean value (64.03%). No reflex component was recorded.

Table 3 Values achieved for the different strength profiles recorded during the test.

CT= (SJ_{PC})+(SJ- SJ_{PC})+(CMJ-SJ)+(ABK-CMJ)+(DJ-CMJA)					
(SJ_{PC})	6.200	%	16.32	CC	Contractile capacity
(SJ- SJ_{PC})	24.33	%	64.04	CRS	Instantaneous recruitment component and muscle fibre synchronization.
(CMJ-SJ)	2.667	%	7.02	CE	Elastic capacity
(CMJA-CMJ)	4.800	%	12.63	CB	Arms use capacity
(DJ-CMJA)	0.000	%	0.00	CR	Reflex component

Figure 4 summarizes table tennis players' strength profile manifestation according to values obtained for each skill that has been described in Table 3.

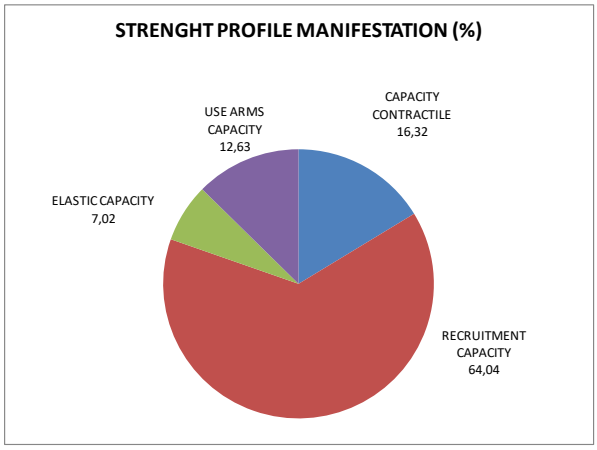

Fig. 4 Strength profile manifestation obtained in the test.

The average values corresponding to elasticity index and reactive arms index are 8.73 and 14.46 cm, respectively (Table 4).

Table 4 Elasticity index (EI) and reactive arms index (RAI) achieved in the test.

Index	Values
EI	8.73
RAI	14.46

Table 5 shows the average values of the strength-velocity index [14] obtained for $SJ_{100\%PC}$ and $SJ_{50\%PC}$, being 78.69 and 52.19, respectively. The Bosco index was 0.2.

Table 5 Strength-velocity (S-V) index and Bosco index recorded in the test.

Index	Values
S-V (100%PC)	79.69
S-V (50%PC)	52.18
Bosco index	0.20

The final values obtained for each strength manifestation are summarized in Table 6, with a value of 80.36% for active manifestation and 19.65% for reactive strength manifestation.

Table 6 Strength manifestation values.

Strength manifestation	%
Active	80.36
Reactive	19.65

4. DISCUSSION

Strength profile manifestation of lower extremities may be achieved expressing every strength manifestation according to the height of different jumps. The equation of Vélez [16] may be applied to correlate different strength manifestations. However, the values obtained with this formula must be taken with caution and considered as an approximation, since investigations about its validity and suitability are limited.

The analysis of strength profile manifestations in table tennis players revealed that active strength components are more important than the reactive ones. Recruitment capacity is essential in the active strength. This means that the tested table tennis players have a good explosive strength profile, as other authors previously reported [9, 17].

A study performed with an elite group of gymnasts [18], also revealed that the synchronization and instant recruitment capacities were predominant. In this investigation, reflex component was minimal, obtaining negative values as occurred with table tennis players. This fact can be explained since the reaction component is not over-stimulated, independently from the maximum pre-stretching induced by the SJ.

There is no unanimity in establishing the ideal elasticity index in a specific population, although in general elasticity must be between 6-9% [19]. In our study, the players achieved a value of 8.73%, being in line with those parameters.

The relationship between different strength manifestations shows that the tested table tennis players have a good strength-velocity relation [20], implying the earlier stimulation of fast muscle fibres [12], that are essential for modern table tennis.

The comparison between the CMJ values achieved in this study with those recorded in others racket sports, such as tennis [21] or badminton [22, 23], revealed that table tennis players achieved lower values (Table 7).

Table 7 Comparison between SJ and CMJ values recorded in several racket sports.

Racket sports	SJ	CMJ
Badminton (Cabello et al., 2000)	-	42.1
Badminton (Hwa ooi et al., 2009)	46.3	42.7
Tenis (Bosco, 1994)	36.5	39
Table Tennis (Pradas et al., 2005)	34.1	36.7

Similar studies performed with an international group of table tennis players [9], reported higher CMJ and SJ values than those recorded in this research (Table 8). This may depend on the moment in which the evaluation was carried out (middle season for the international players vs. beginning of the season in our study).

Table 8 Comparison between SJ and CMJ values recorded in this study with those achieved with international players [9].

	SJ (cm)	Maximum (cm)	Minimum (cm)	CMJ (cm)	Maximum (cm)	Minimum (cm)
International players	34.14±5	41.7	25.2	36.76±5.6	44.4	27.3
National players	30±3	34	25	33.2±2.4	37	29.6

Further investigations involving a larger group of players in different moments of the season are needed for corroborating the results achieved in this study.

5. CONCLUSSIONS

The active strength manifestations (recruitment capacity and contractile capacity) are the predominant strength expression in table tennis players.

Explosive strength is the most important manifestation in this sport. It is the consequence of lower extremities movements that are performed at maximum velocity and acceleration and are associated with the fast achievement of the ideal position to hit the ball accurately.

The assessment of jump capacity in lower extremities represents an effective method to assess several strength manifestations and to analyse performance in table tennis.

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