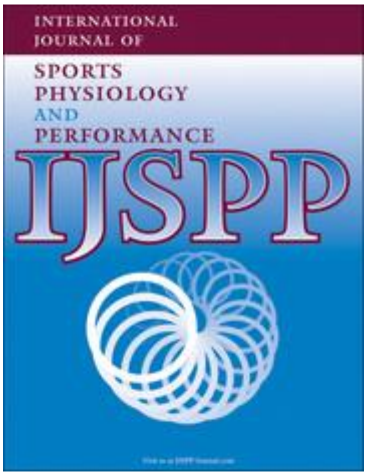

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Title: Shooting performance and fly time in highly-trained wing handball players: not everything is as it seems

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1. Abstract

Purpose: The aims of this investigation were to 1) assess the usefulness of counter movement jump (CMJ) testing to predict handball-specific jumping ability and 2) examine the acute effect of transiently- modified jumping ability (i.e., flight time) on shooting efficiency in wing players. ***Methods:*** Eleven young highly-trained wing players performed 3 counter movement jumps and 10 typical wing jump shots with 3 different modalities: without any constraint (CONTROL), while stepping on a 14-cm step (STEP) and wearing a weighted vest (VEST, 5% of body mass). Flight time and the associated scoring efficiency during the jump shots were recorded. ***Results***: There was no clear correlation between jump shot and CMJ flight time, irrespective of the condition (r=0.04-0.18). During jump shots, flight time was most likely longer (ES=1.42-1.97) with VEST (635.4±31 ms) and STEP (615.3±32.9 ms) than CONTROL (566±30.5 ms) and very likely longer with VEST than with STEP (ES=0.6). The correlation between scoring efficiency and jump shot flight time was not substantial both within each modality and for all shots pooled. The difference in scoring efficiency between the 3 jumps with the longest vs. shortest flight times were either small (VEST, 48% vs. 42%) or non-substantial (two other conditions). ***Conclusions***: The use of CMJ as a predictor of handball-specific jumping ability is questioned given the dissociation between CMJ and jump shot flying time. These results also show that transiently-affected flight time may not affect scoring efficiency, which questions the importance of jumping ability for success in wing players.

Key Words: shooting efficiency; strength training; transfer

2. Introduction

Handball is an Olympic sport played widely across the world, with more than 19 million players competing at the club, regional, national and international levels from amateur to professional standards (e.g., in France[1]). In addition to technical and tactical skills, Handball is also a strenuous intermittent sport which requires specific and well-developed physical capacities to be successful (e.g. explosive strength, endurance and sprinting abilities).[2]

An important consideration in team sports, and particularly in Handball, is that playing demands are position-dependent, and require therefore different physical, anthropometric (e.g., body mass, height[3-5]) and physiological[4-6] attributes. For example, while the ability to jump is likely important for all positions, it may be even more determinant for wing players due to their lateral position on the court and the restricted space they play in.[2,6] For these reasons, the assessment of jumping abilities is common practice in handball for both talent identification and training monitoring. [7,8] However, it is still unknown whether typical testing protocols such as counter movement jumps (CMJ) do actually predict handball-specific jumping ability (i.e., the actual duration of a jump shot on the court, when holding the ball and using a single-leg impulsion).

Regarding performance enhancement, two intervention studies in handball have shown that both maximal strength and plyometric training improved CMJ performance very largely (9.5[9] and 14[10] %, respectively). However, whether those gains are transferable into the game in term of shooting efficiency is still unclear. For example, the actual performance benefit of an increased throwing velocity *per se* needs to be considered in relation to game situations, where players may not manage to always use their full jumping potential.[11] In general, the transfer of training-induced physical improvements into enhanced technical performance are difficult to predict in team sports given the complexity of the factors leading to the final performance outcomes.[12]

Therefore, the first aim of this study was to assess the usefulness of CMJ testing to predict handball-specific jumping ability (i.e., the actual duration of a jump shot on the court when holding the ball and using a single-leg impulsion). The second aim of this study was to examine the acute effect of transiently-modified jumping ability (i.e., flight time) on shooting efficiency in wing players.

3. Methods

Study overview. The tests took place during a typical in-season training week (on Thursday). In order to measure the effect of flight time on wing players' shooting efficiency, we used three different jump modalities: 1) without any constraint (CONTROL), 2) with a weighted vest (VEST) corresponding to 5% of the body mass (to the nearest 500 g) and 3) while stepping on a 14-cm step (STEP). Players performed 10 jump shots and 2 CMJs within each modality. The same operator (an experienced trainer with >20 years of high level training) checked that all players paid attention: 1) to start with a foot on the angle of the court (intersection of the lateral and back lines, Figure 1), 2) to make exactly 3 steps before the jump, 3) to impulse with their stronger leg, 4) not to step in the 6-meter zone, and 5) to land on their feet without exaggerated knee flexion (≤70°). Players were requested to repeat the jump if these latter rules were not followed. During all CMJs, participants were asked to keep their hands on their hips. The depth of the countermovement jumps was self-selected to minimize intervention. For greater standardization, players were requested to land on their toes, minimizing knees flexion.

An experienced tester checked all landings; players were requested to repeat the jump if landing procedures were not consistent. All athletes were verbally encouraged throughout the tests and asked to jump as high as possible. These CMJs were used to assess the effect of the different modalities on jumping height/time *per se*. Since players can use different strategies to beat the goalkeeper (i.e., jumping further to overcome him vs. higher to shoot trough him (between the legs, the arms) or a combination of the both, we decided to consider flight time as indicator of jump shot performance. For jump shots, the takeoff zones were located 2.75 m from the corner point and 1.89 m from the court line (Figure 1). When players did not land with at least one foot between the two optojump units (2-m apart), or when they did not jump while using their stronger leg (i.e., left leg for a right-handed player and right leg for a left-handed player), the trial was not recorded and was repeated. Shooting efficiency (%) was assessed as the ratio between the numbers of goals scored and the numbers of shots taken.

Subjects. Eleven highly-trained (11-12 hr per week) wing players distributed in six right (182±4.9 cm, 69.3±6.8 kg and 16.6±1.1 years) and five left wings (178.2±9.1 cm, 67.5±11.9 kg and 15.9±1 years) shot within a single session on the same goalkeepers. All the players were part of a regional training center, they had played handball for 8.02±1.9 years and some of these players were selected in the national groups of their respective age category. In total, players performed 30 jump shots, i.e., 10 CONTROL, 10 VEST and 10 STEP modality.

Materials: Flight times during the jump shots and CMJs were recorded with a 5- (jump shots) and 1- (CMJ) m Optojump next (Microgate Co., Bolzano, Italia), respectively, which was connected to a laptop with the provided software (Optojump Next v. 1.10.7.0). The additional mass on the weight vest was equally distributed between each side of the body (left and right, back and front) (Domyos, Decathlon, Villeneuve d'Ascq France).

Statistical Analyses. Data in the text and figures are presented as means with standard deviations (SD) and 90% confidence limits/intervals (CL/CI). All data were first log-transformed to reduce bias arising from non-uniformity error. In order to compare the effect of the different jumping modalities within and between CMJs and jump shots, standardized differences in the mean (Cohen's effect size) were first calculated (with 90% CI) using the longest CMJs and the longest jump shot for each player.[13] The differences were also analyzed for practical significance using magnitude-based inferences.[14] Probabilities were used to make a qualitative probabilistic mechanistic inference about the true differences: if the probabilities of the differences being substantially greater and smaller than the smallest worthwhile difference (0.2 of the between-player SD) were both >5%, the effect was reported as unclear; the effect was otherwise clear and reported as the magnitude of the observed value. The scale was as follows: 25% to 75%, possible; 75% to 95%, likely; 95% to 99%, very likely; >99%, almost certain. The effect of transiently modified jumping ability (i.e., flight time) on shooting efficiency was examined for all the players pooled together but also for right and left wings separately. We then calculated the difference in flight time of the three longest vs. three shortest jump within each modality for each player, and for the 10 longest and 10 shortest jump shots for all modalities pooled. Finally, we calculated the difference in scoring efficiency during the 3 longest vs. the 3 shortest flight times within each modality for each player, and for the 10 longest and 10 shortest jump shots for all modalities pooled. Finally, pearson's correlation analysis was used to investigate the relation between i) flight-time in the jump shot vs. CMJ. ii) mean scoring percentages and mean flight time within each modality (CONTROL, VEST, STEP) and for all jumps/shots pooled together. The following criteria were adopted to interpret the magnitude of the correlation (r): ≤0.1, trivial; >0.1–0.3, small; >0.3–0.5, moderate; >0.5–0.7, large; >0.7–0.9, very large; and >0.9–1.0, almost perfect. If the 90% CI overlapped small positive and negative values, the magnitude was deemed unclear.[14] Odds ratio were calculated to compare players ‘scoring efficiency between the different modalities. The magnitudes of the odds ratio were interpreted using Hopkins scale.[14] All statistical analyses were conducted using Microsoft Excel (Microsoft, Redmond, WA, USA).

4. Results

The average within-player variation in jump shot flying time was 60 ± 20 ms (90% CL) or 15.3 ± 1.7 % (rated as moderate when standardized) for CONTROL, 30 ± 10 ms or 4.3 ± 0.6 % (moderate) for STEP and 60 ± 20 ms (90% CL) or 13.5 ± 1.5 % for VEST.

The standardized differences in flying time between each jump modality are shown in Table 1. During CMJs, flight time was most likely moderately-to-largely longer with STEP than CONTROL and VEST, and likely slightly longer for CONTROL than for VEST.

During jump shots, flight time was most likely largely longer with VEST and STEP than CONTROL, and very likely slightly longer with the VEST than the STEP (Table 1).

There was no substantial association between the flight time during jump shot and CMJs, irrespective of the modality (Figure 2).

Scoring percentages are shown in Table 1 (Table 1). Left wings were slightly more efficient with the STEP than with the CONTROL modality (OR=2.13, CI= 1.21 to 3.75). There was no clear association between scoring efficiency and flight time, irrespective of the modality (Figure 3).

The difference in scoring efficiency between the longest and worst shortest jumps were either small (VEST, 48% vs. 42%) or non-substantial for the other modalities (Figure 4).

5. Discussion

The aims of the present study were to 1) assess the usefulness of CMJ testing to predict handball-specific jumping ability and 2) examine the acute effect of transiently-modified jumping ability (i.e., flight time) on shooting efficiency in wing players. We report here for the first time that there may not be any clear association between CMJ and jump shot flight times, and that scoring efficiency may not be related to flight time during jump shots from the wing position.

The present study revealed that there was no clear association between CMJ and jump shot flight times, suggesting that these two types of jump have specific technical and motor components. While CMJ is a common test in handball, both for talent identification[7] and training monitoring,[8] the present data may question the use of CMJ as a predictor of handball-specific jumping ability. A first explanation could be that a jump shot from the wing position requires a higher coordination level (e.g., dissociation between the upper and lower body with a rotation of the body in the air) than a CMJ. Another explanation is that jump shot requires both vertical and horizontal force application components, which are now clearly considered as different neuromuscular capacities.[15] While these results suggest that more handball- specific jump testing protocol should be developed in the future,[15] CMJ testing may still be useful for profiling purposes when assessing general physical qualities (i.e., using CMJ as an index of player's overall explosive strength) and monitoring neuromuscular fatigue.[16] The actual magnitude of the dissociation between both types of tests may inform on player's physical vs. coordinative profile, and could provide individualized training directions. For example, a player with a good CMJ performance (i.e., well above his team average) but an average jump shot performance may need to first improve his coordination and handball-specific skills. Conversely, it could be assumed that a player with a good jump shot performance in comparison to his relative CMJ performance may benefit more from strength training. The interest of this latter profiling approach should however be balanced with respect to the second main finding of the present study, i.e., the lack of association between scoring efficiency and flight times during jump shots.

An unexpected finding of the present study was that while the weighted VEST had a negative effect (-2.9%) on CMJ flight time as expected, we observed a positive impact (+10.9%) of the additional loading on jump shot performance. This apparent increase in jump performance may however be an artifact related to the fact that flight times can be affected by differences in body configuration between take-off and landing, independently of the actual jump performance. Due to the nature of handball jump shots, where players tend to vary their body inclination and delay their shot as much as possible to beat the goalkeeper, it was impossible to standardize body configuration between each shot and between the different conditions; this is a clear limitation of the study. Another limitation is that athletes may have also compensated for wearing weighted vests by pulling up their legs prior to landing. While an experienced coach checked that all landings were consistent, this could not be perfectly controlled due to the nature of jump shots.

Previous studies have suggested that a high jumping ability may be advantageous for wings, since they are generally reported to jump higher than the other outfield players.[2] Our present findings suggest however that the relationship between scoring efficacy and jumping ability may be more complex than previously thought. If changes (even the largest, see Figure 3 & 4) in flight time do not affect scoring efficiency, we can speculate that some other factors play also a role, such as for example coordination (e.g., jumping technique, dissociation of the pelvic and scapular girdle, arm position during the jump), technical skills and decision making ability (e.g. shooting variety and relevance in relation to the goalkeeper moves). The differences in scoring efficiency (47.1% and 50.2% respectively) found between left and right wing players in the CONTROL vs. the STEP modalities could be explained by the fact that goalkeepers take generally less shoots from left handed players, especially during training sessions (since teams include less left-handed players; generally, 4 or less, which represents only 25% of the team).[2]

It is worth noting however that the present results need to be considered while considering the present protocol (i.e., transiently-increased jump abilities), and that inferences to different players with varying jumping abilities and/or long-term changes in jumping performance must be taken cautiously. In fact, with transient modifications of their flight times, players didn't have the time to adapt to their enhanced/impaired jumping performance. This could have affected their usual shooting technique and decision making skills, which could, in turn, explains the limited effect on scoring efficiency.[17] In contrast however, we believe that our approach had the advantage of allowing the isolation of the probable effect a short strength training program on lower-limb explosive strength and in turn, jump time, while avoiding the confounding effect of likely technical/perceptual/decision making improvements that may occur concomitantly. More studies are still needed however in a more skilled population, since it is possible that elite wing players may adapt more efficiently to variations in flight times. The effect of player's laterality on scoring efficiency is another aspect that warrants further investigation.

Since we only recorded flight time, which is only a global indicator of jump performance, we could not examine the respective importance of jump height, distance or their combination for improved scoring efficiency. It is also worth noting that the actual shooting efficiency reported here may be directly related to the skills and experience of our goalkeeper. We believed however that this may have only little effect on the comparisons examined in the present study, since all players, under all conditions, shot against the same goalkeeper.

6. Practical applications

Our results suggest that the importance of CMJ performance for talent identification may have to be reconsidered, and confirm that wing players' technical skills should not be overlooked. Our results also question the value of specific strength training programs to increase vertical jump for wing players. The actual magnitude of the dissociation between CMJ and jump short performance may however inform on player's physical vs. coordinative profile, and could provide individualized training directions. Since training with a weight vest (5% of body weight) may results in an increased flight time, such an intervention could be used as a motivational factor during technical training as a mean to transiently improve jump shot conditions in wing players.

7. Conclusions

The use of CMJ as a predictor of handball-specific jumping ability is questioned given the dissociation between CMJ and jump shot flying time. Transiently-increased jumping ability doesn't appear to affect shooting efficiency on highly-trained wing handball players. Whether this results from the design of the study (i.e., lack of time to adapt), the characteristics of the population or from the technical component of the wing jump shot is still unclear.

8. Acknowledgement

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Figure legends

Figure 1. A and B. Illustration of the experimental set up to measure jump shot flight time (A and B). **C.** a ring wing player wearing the weight-vest.

Figure 2. Longest flight time for jump shot and counter movement jump in the CONTROL, STEP and VEST modalities. Correlation coefficients are given with 90% confidence intervals.

Figure 3. Relationships between mean scoring efficiency (%) for the jump shot and mean jump shot (ms) flight time in the VEST, STEP and CONTROL modalities, and for all modalities pooled. Correlation coefficients are given with 90% confidence intervals.

Figure 4. A. Average flight time for the 3 longest and 3 shortest jump shots, expressed as a percentage of average flight time within each jump modality, and for the 10 longest and 10 shortest jump shots for all modalities pooled. # stands for a very large difference, ## for a nearly perfect difference between longest and shortest jump shots. **B.** Mean jump shots scoring efficiency during the 3 longest and the 3 shortest flight times within each jump modality, and for the 10 longest and 10 shortest jump shots for all modalities pooled. * stands for a small difference between longest and shortest flight time.

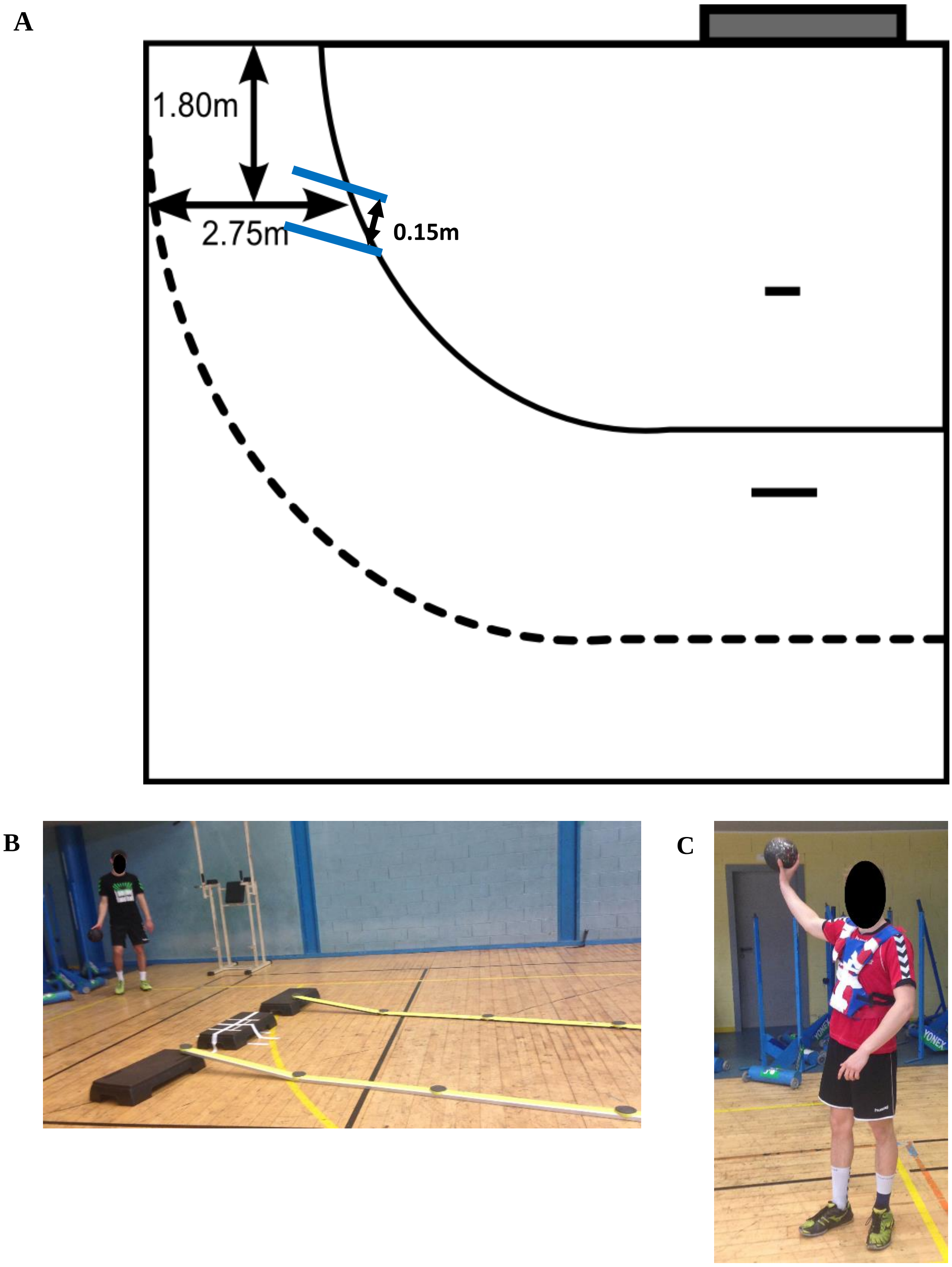
Table 1. Longest flight time (flight time±SD) for each modality during counter movement jump and jump shot. ES (standardized difference), rating, lower and upper value of 90% confidence limit (CI), likelihood of difference (%), and rating for counter movement jump and jump shot.

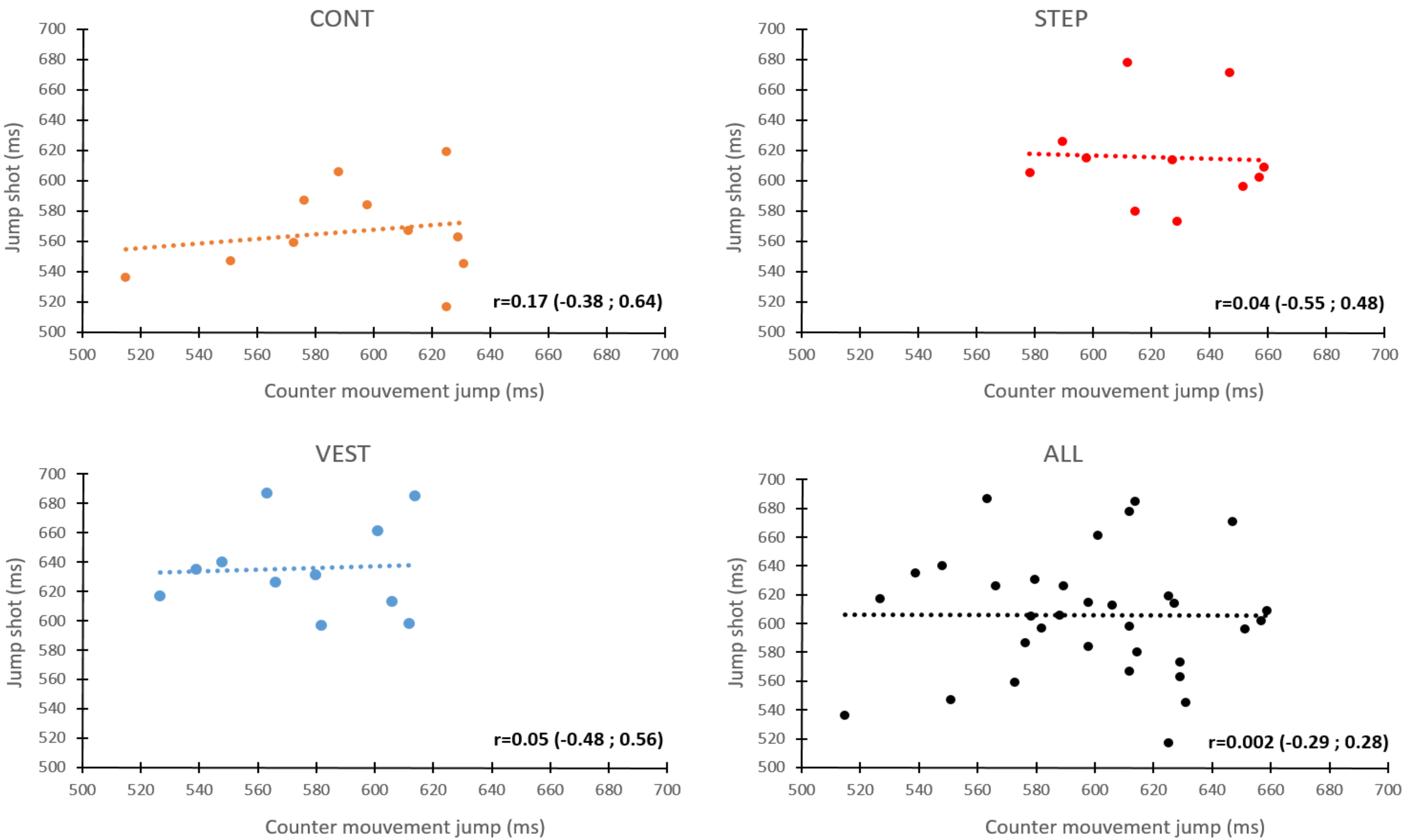
				Counter mouvement jump			
	Time (ms)		**ES**	**Rating**	**CI**	**Likelihood of difference (%)**	**Rating**
CONTROL	592±37						
		vs. STEP	- 0.74	moderate	-0.45 ; -1.03	100	Most likely
		vs. VEST	0.40	Small	0.12 ; 0.79	89	Likely
VEST	576±30						
		vs. STEP	-1.39	Large	-1.47 ; 1.32	100	Most likely
STEP	623±28						
				Jump shot			
	Time (ms)		**ES**	**Rating**		**Likelihood of difference (%)**	**Rating**
CONTROL	566±30						
		vs. STEP	-1.42	Large	-1.80 ; -1.05	100	Most likely
		vs. VEST	-1.97	Large	-2.37 ; -1.58	100	Most likely
VEST	635±31						
		vs. STEP	0.61	Moderate	0.23 ; 1.01	96	Very likely
STEP	615±33						

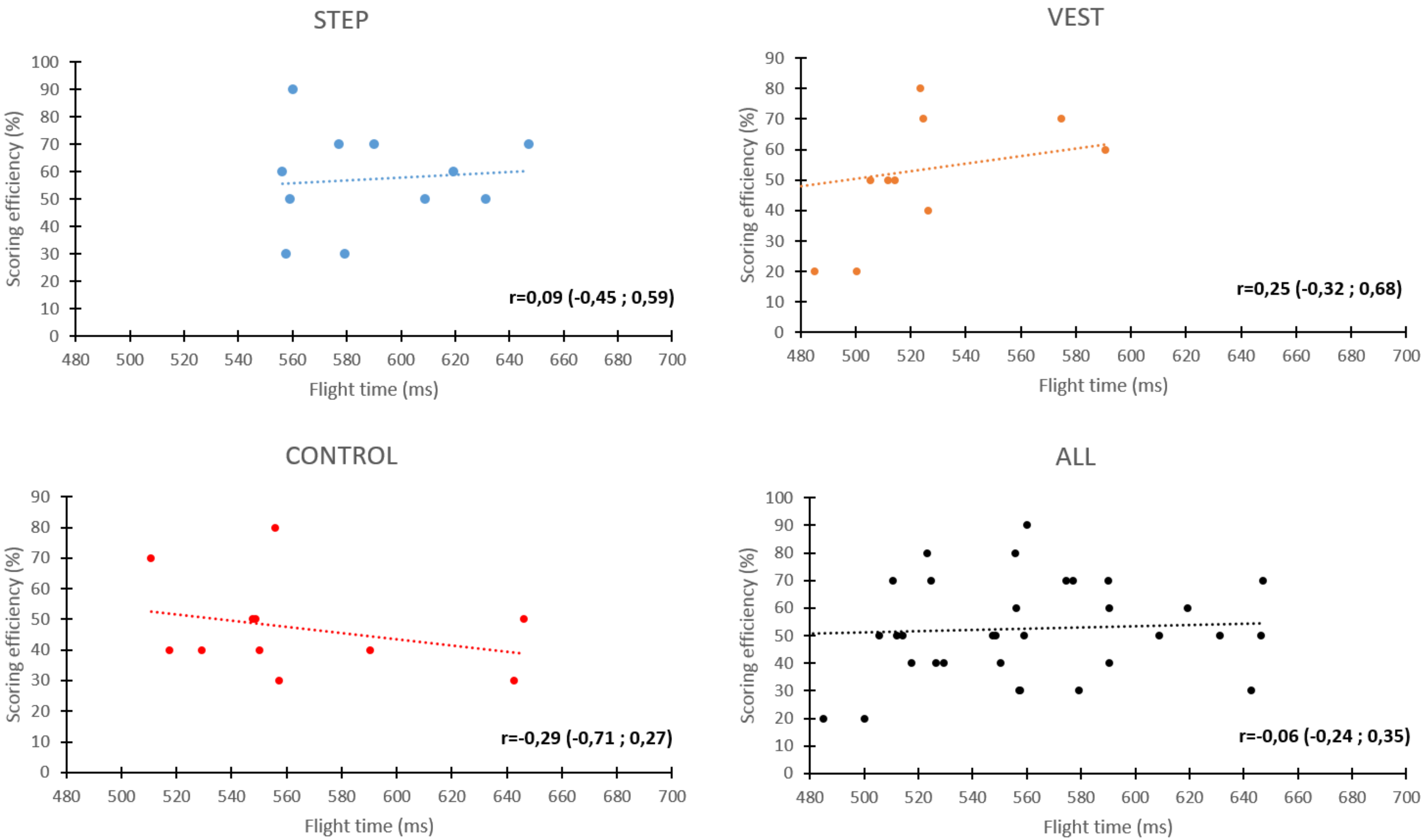
Table 2. Scoring efficiency with respect to playing positions and jump shot modalities

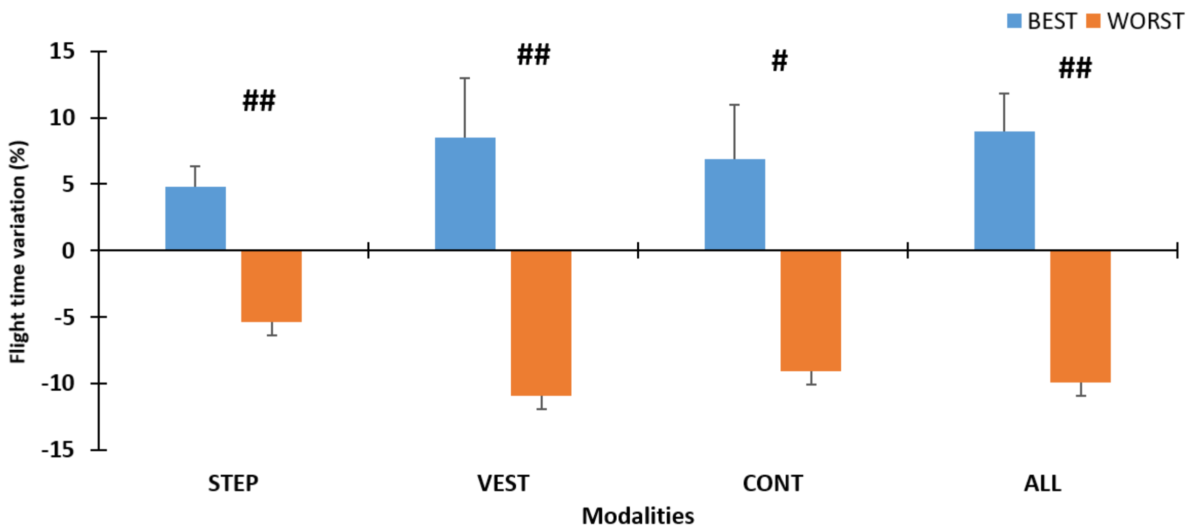
	CONTROL	STEP	VEST
All	42.6±15.3%	54.6±20.6%	54.6±16.4%
Left wings	37.1±7.6%	55.7±14%*	48.6±17.7%
Right wings	48.6±19.1%	57.1±19.2%	61.4±22.7%

* small difference in odds ratio vs. CONTROL.

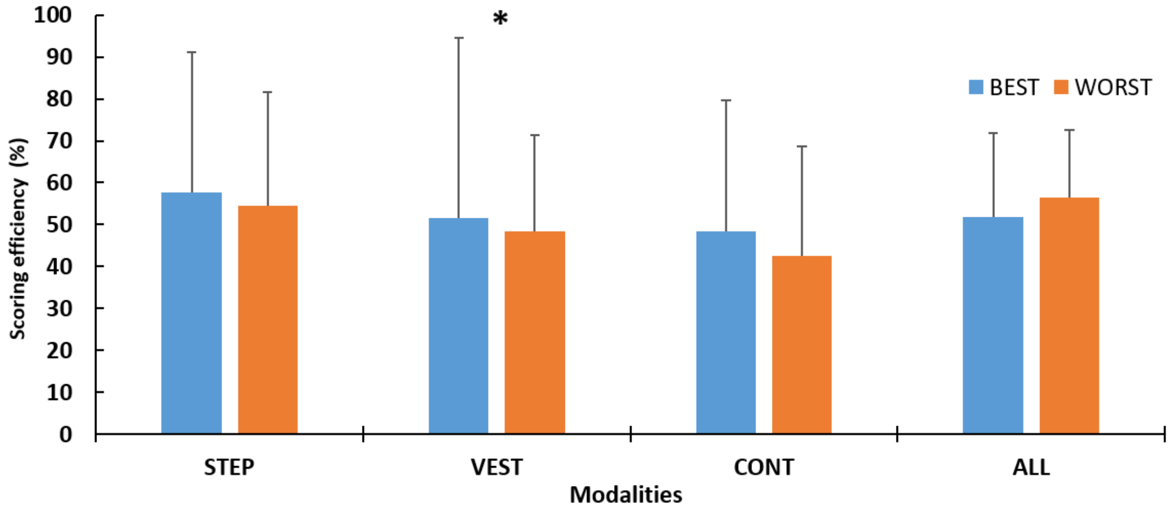

A
1.80m
2.75m
0.15m
B
C


CONT
r=0.17 (-0.38 ; 0.64)
STEP
r=0.04 (-0.55 ; 0.48)
VEST
r=0.05 (-0.48 ; 0.56)
ALL
r=0.002 (-0.29 ; 0.28)
Jump shot (ms)
Counter mouvement jump (ms)
500
520
540
560
580
600
620
640
660
680
700


STEP
Scoring efficiency (%)
Flight time (ms)
r=0,09 (-0,45 ; 0,59)
VEST
Scoring efficiency (%)
Flight time (ms)
r=0,25 (-0,32 ; 0,68)
CONTROL
Scoring efficiency (%)
Flight time (ms)
r=-0,29 (-0,71 ; 0,27)
ALL
Scoring efficiency (%)
Flight time (ms)
r=-0,06 (-0,24 ; 0,35)



BEST
WORST
15
10
5
0
-5
-10
-15
Flight time variation (%)
##
##
#
##
STEP
VEST
CONT
ALL
Modalities



100
90
80
70
60
50
40
30
20
10
0
Scoring efficiency (%)
*
BEST
WORST
STEP
VEST
CONT
ALL
Modalities