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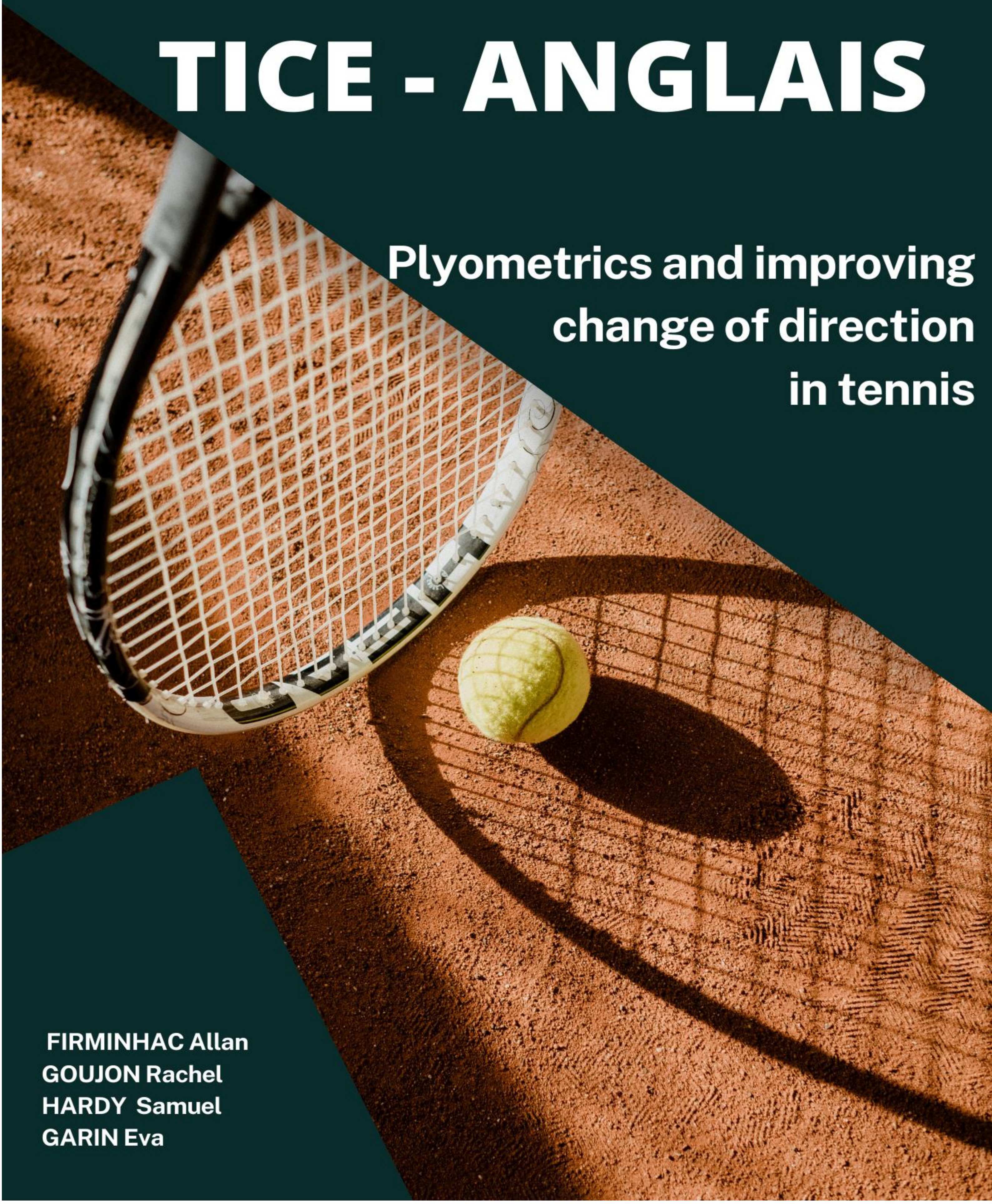
TICE - ANGLAIS

Plyometrics and improving change of direction in tennis



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Summary

The Effects of Plyometric Training upon Change-of-Direction Performance for Tennis Players

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Abstract

Purpose: The purpose of this study was to investigate the effects of 5 weeks of plyometric training upon change of direction performance.

Methods: A total of four athletes from different sports specialities participated in the study. The training program took place over 5 weeks, with a total of 10 sessions, including 2 tests sessions. During the training sessions, different plyometric exercises were used, including some horizontal and vertical jump. The monitoring of the training load was done using a the individual variation of the reactive strength index.

Results: The statistical analysis of the results before and after the training program demonstrated a significant improvement in both Reactive Strength Index and change of direction.

Conclusion: In conclusion, this study demonstrates that plyometric training leads to a significant improvement in change of direction performance.

Keywords: Change-of-Direction; specificity; plyometrics; tennis

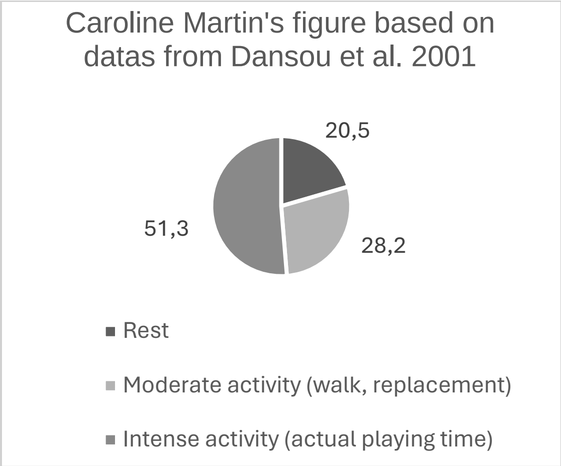
Introduction

Tennis is a complex sport, which involves various physical abilities.

Temporal characteristics of a tennis match

One of the most important characteristics of tennis matches is their temporality.
In fact most of the matches are in the best of three sets. And each sets can have huge differences in time duration, but the average duration of a full match is around one hour and a half. But there are some exceptions, during masculine Grand Slam, matches are in the best of five sets which lead to way longer matches than conventional matches in the best of three. Most of them occurred for more than 2 hours (Morante S.M., 2005), and the longest match ever played lasted over 11 hours.

In a tennis match, there is a lot of recuperation time.



As we can see in the figure above, the actual playing time represent less than 30% of the total duration of the match.

All those information about the temporal characteristics of a tennis match have necessarily an influence on the physiological demands.

Physiological demands of tennis

Tennis is a physiologically demanding activity, involving both aerobic and anaerobic energy systems. During intense playing phases such as ball strikes, anaerobic metabolism predominates, accounting for up to 95% of energy expenditure. However, over a period of time including points and recovery phases, aerobic metabolism becomes predominant, contributing to around 70% of total energy expenditure.

The average energy expenditure of a tennis match varies depending on the level of play, type of player, and match type, with an estimate of around 1850 kJ/hour in junior players at national and international levels (Novas A.M.P., 2003). The main energy substrates used are carbohydrates, accounting for 70 to 80% of total energy supply, while the contribution of lipids increases with the duration of play.

Oxygen consumption varies throughout the match, with average VO2 levels fluctuating between 46 and 80% of VO2max. Heart rate increases during exchanges and decreases during recovery periods, with average values between 135 and 161 bpm (Martin, 2018). Lactate levels, although relatively low on average, can increase during intense playing phases, which can affect players' performance

Deplacement and strikes of a tennis player

In tennis, players typically cover between 3 and 3.5 kilometers per match (Hoppe M.W., 2014), with a difference between men and women, men usually covering a greater distance. On surfaces like clay, players cover even more distance. During points, players cover between 500 and 800 meters per set, with an increase for matches in 5 sets. Winners of matches and points tend to cover more distance than losers.

In youth tennis, movements are slightly slower than among pros. Losers tend to move more than winners, but the influence of playing style and surface remains to be studied.

The number of strikes varies depending on the tournament, with more strikes at Roland Garros (clay court) and fewer at Wimbledon (grass court). Players generally make more strikes during their serves than during returns.

Most strikes occur nearby, with little movement. Players mainly perform quick stop-and-start movements, with frequent changes in direction. They spend most of their time walking, with occasional periods of moderate or sprinting, especially among professionals.

Change-of-Direction ability

The ability of Change-of-Direction is really important in a sport such as tennis, in order to be able to react from the received ball.

The change of direction ability refers to an athlete's capacity to execute quick and precise movements to change direction while maintaining control and speed. This ability is crucial in many sports, such as tennis, where athletes must react promptly to changes in the situation on the field. Contrary to common assumptions, research indicates a clear distinction between straight-line sprint speed and the ability to change direction, with these two qualities being specific and requiring distinct skills. (Young, 2007) demonstrated that even if an athlete is fast in straight-line sprints, it does not guarantee equivalent performances in situations involving changes of direction. Furthermore, it has been observed that training focused solely on improving straight-line sprint speed does not necessarily enhance change of direction ability.

The key factor to improve COD (Change of Direction) is to improve RSI (Reactive Strength Index).

Plyometrics

Plyometrics is a training method used by athletes in various sports to enhance their strength and explosiveness. This technique involves rapid stretching followed immediately by a muscular contraction, allowing the stored elastic energy within the muscle to generate greater force than possible with a singular muscular contraction. Plyometric exercises, such as jumps, explosive starts, and rapid directional changes, aim to develop agility, defined as the ability to quickly control the body's position while changing direction. Plyometric training is often combined with a periodized strength training program for optimal improvements in performance, including vertical jump, acceleration, leg strength, muscle power, joint awareness, and proprioception. While scientific evidence regarding the effects of plyometrics on agility remains limited, this method is widely employed in various sports to optimize athlete performance.

The combined research of (Michael G. Miller, 2006) and (Håvard Guldteig Rædergård, 2020) show the importance and benefits of plyometric training for athletes, particularly in enhancing agility and change of direction capabilities. Plyometric training offers an effective method for improving athletes' strength, explosiveness, and agility, with benefits observed in as little as 6 weeks. Furthermore, this training method can be particularly advantageous during preparatory phases before in-season competitions, providing athletes with a means to develop specific skills such as the ability to rapidly respond to pronounced changes in direction. However, it is crucial for coaches to carefully tailor training programs to individual athletes' needs, taking into account factors such as their level of maximal strength in the lower limbs. Overall, plyometrics emerges as an effective strategy for enhancing athletic performance, offering tangible benefits in terms of strength, power, and agility.

The purpose of the study, is to determine how plyometric training can improve change of direction ability for tennis players. The hypothesis is that plyometric training will improve change of direction ability for tennis players by improving their reactive strength index, so their ability to have a shorter contact time but also develop an important strength.

Materials and Methods

Table 1- Participants characteristics' data

	Allan	Eva	Rachel	Samuel	Mean	SD
Age (years)	22	21	20	21	21	0,82
Height (cm)	186	171	180	183	180	6,48
Body Mass (kg)	68	74	63	69	68,5	4,51

Participants

Four students in sport sciences (one competitive, one recreational, and two beginner tennis players) were recruited in this study. The participants belonged to the same university and were physically healthy, free from sever low-body injuries. The players undertook two training sessions per week with each session lasting about one hours. One of the participants couldn't participate to more than a half of the training sessions, this is why he was excluded from the results, in order to not interfere in the interpretations of our protocol.

Procedures

Prior to the intervention study, the participants were involved in session of familiarization. During this session, they performed change of direction test and plyometric test. The aim of this session of familiarization was to reduce the learning bias, which could interferes in our results.

The first session was dedicated to the tests, the training program took place during the next eight sessions, and the last session was another test session.

Test Program

Cooke Test

Figure 1 - Cooke Test

Link to the video of Cooke Test: https://dartfi.sh/mMeQkba9n2a

We found this test in the article (Cooke, Quinn, & Sibte, 2011) which we found relevant. This test is conducted over distances of 3 m, between the starting point and three doors. One door is directly opposite the starting point, another to the right, and the last one to the left with a distance of 1 m between them. In tennis, sprints rarely exceed 3 m. That's why we found this test to be quite representative. We conducted it in two different ways and repeated it three times each to obtain averages.

The first time, we conducted it with certainty. We knew the order of the doors to be passed through in advance. The other way was to do it with uncertainties, where the direction to take was given at the last moment with a visual stimulus. The purpose of this stimulus was to react as quickly as possible to move towards the indicated door.

We conducted it in these two ways because we wanted to compare the times achieved with certainty and with uncertainties. The goal was to eliminate the notion of agility in the time it takes for athletes to react to stimuli. Visual stimulus was chosen because in tennis, it's the sense most stimulated during matches by ball exchanges. Subsequently, we analysed the results by looking at the time taken by the athlete during the changes of direction and the return. For the outbound and return journeys, we focused on the moment when the athlete physically engaged in an intention to move in the given direction for the certainty condition. Then, for the uncertainty condition, we based it on the moment of visual information intake by the athlete. The time was stopped when one foot was in contact with the ground beyond the indicated door. For changes of direction, we took the time from the moment the foot was in contact with the ground beyond the door until the same foot was no longer in contact with that ground.

Reactive Strength Index Test

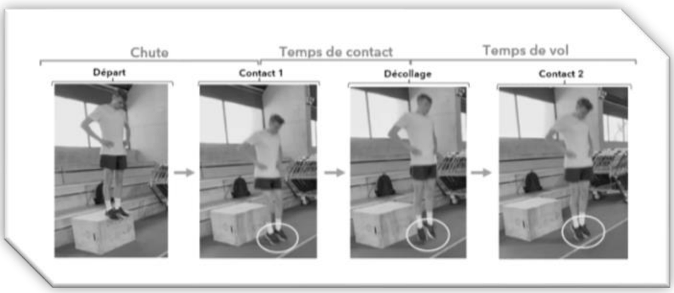


Figure 2 - Drop Jump interpretation

Link to the video of RSI Test: https://dartfi.sh/mo11FgHOCp1

The test was applied to evaluate athletes' performance in plyometrics, by measuring how fast is the strength-shortening cycle of the lower body.

When performing this test, the athletes were instructed to "walk out" from the box in order to prevent increased drop height by an eventual vertical impulsion to get out the box. The eventual use of the arms was standardize by asking the athletes to keep their hands on their hips during the all jump.

The evaluation of ground contact time and jump height were doing on *My jump lab* app. The app registers contact time and flight time and calculates jump height based on the following equation : $jump\ height = flight\ time^2 \times 1{,}22625$. The RSI is calculated using the following equation $RSI = \frac{jump\ height\ (in\ m)}{contact\ time\ (in\ s)}$.

Training Program

Link to the video of the training program: https://dartfi.sh/8RtJZViCfK6

Subjects were encourage to perform each drill with maximum intensity, with a fast switch between excentric to concentric contraction in order to have the minimum ground contact time as possible.

Training took place two days per weeks, on Tuesday and Friday in order to have sufficient rest time between both sessions.

The training program included different plyometric exercises. Here are some of them: Unilateral CMJ, Drop jump, Unilateral Hurdle jump, Bilateral Hurdle jump, and Skate jump. The order of the exercises, the number of sets, and the recovery time were adjusted according to the weeks. The details of all the sessions is in the annexes.

Monitoring training load

Each athletes had to do a RSI test at the beginning of each training session, in order to know their physical capacities of the day. During the test session, the optimal jump height was determined for each subject. An average of the three jumps performed at the determined height was taken to define a standard deviation. At the beginning of each session, participants performed a jump at the optimal height, followed by a comparison with the mean value +/- the standard deviation. If the value falls within this range, it indicates that the athlete is in good shape. Conversely, a value lower than this indicates some neuromuscular fatigue in the subject, while a higher value indicates good physical condition. Thus, determining the optimal height relies on the Reactive Strength Index (RSI) results obtained via the drop jump. (Ebben & Petushek, 2010) has shown that RSI is considered a reliable indicator of explosiveness and the ability to generate maximum force in a short period. Therefore, it can also be used as an index of neuromuscular fatigue. The correlation between RSI and neuromuscular fatigue thus allows quantifying the athlete's fitness level accurately at the beginning of the session. Furthermore, the article highlights the significant impact of box height on drop jump performance. This observation justifies using pre-session RSI results to evaluate athlete fatigue and accordingly adjust session content. This evaluation methodology allows adjusting rest times or exercise intensity based on the level of fatigue.

Cf. Figure 18 - Graph of monitoring training load

Statistical Analysis

For the analyse of the results, different statistic methods were used to assess the effect of plyometric training upon change of direction performances.

T-test Bayesian

This test was made with JASP's application. This test is used to know if there is a significant difference between the pre- and post- values of the group. The aim was to know if there is a difference between both measure, without indicating if this difference have to be positive or negative.

Effect size with Hedges' g

Hedges' g is a measure of effect size. This statistical analyse was used to know how much one group differs from another (in our case how much pre- values differ from post- values) Hedges' g is calculated using the following equation : $g = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{(n_1-1)*S_1{}^2+(n_2-1)*S_2{}^2)}{n_1+n_2-2}}}$ where $\bar{x}_1$, $\bar{x}_2$ are respectively the mean of sample 1 and sample 2; n_1, n_2 are

respectively the size of sample 1 and sample 2; $S_1{}^2$, $S_2{}^2$ are respectively the variance of sample 1 and sample 2. The calculator developed by *Statology* was used to simplify Hedges' g calculations.

A Hedges' g of 0,2 is considered as a small effect size, 0,5 is a medium effect size and 0,8 is a large effect size.

Results

The statistical analysis of the results in pre- and post- training program showed a significant improvement in the Reactive Strength Index (RSI) at 30 cm for all participants. However, regarding the RSI at 50 cm, only one participant demonstrated improvement, while one remained at the same level and another showed a decrease in performance. No improvement was observed for the RSI at 60 cm. Regarding the change of direction tests, in planned and reactive conditions, a decrease in execution time was observed for all participant.

Table 2 - Statistical analysis RSI at 30 cm (pre- and post- test)

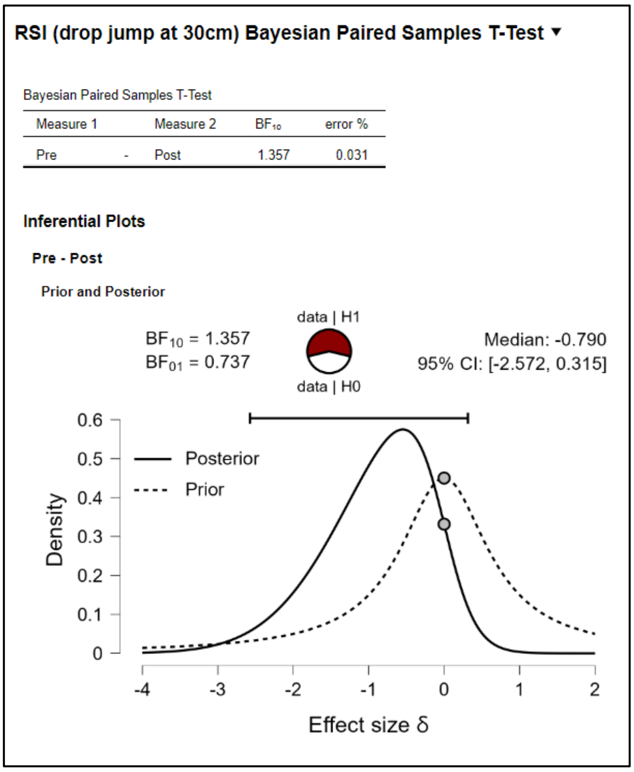


Figure 3 - Bayesian paired samples T-test (RSI at 30cm)

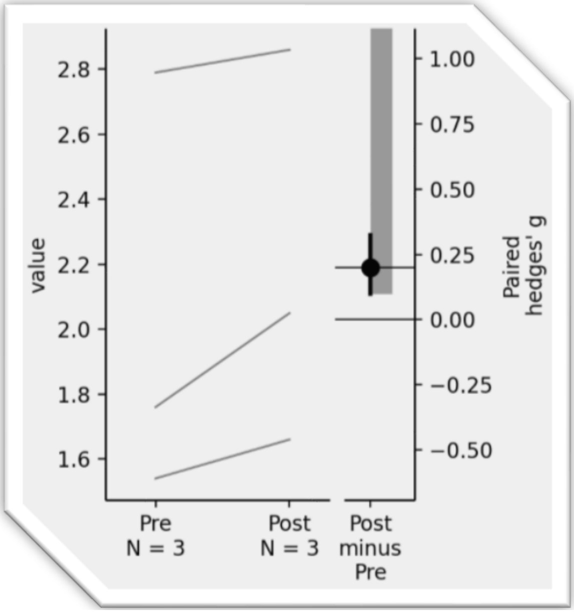


Figure 4 - Graph with individual evolutions and hedges' g (RSI at 30cm)

Hedges' g: **0.249878**

"statology.org"

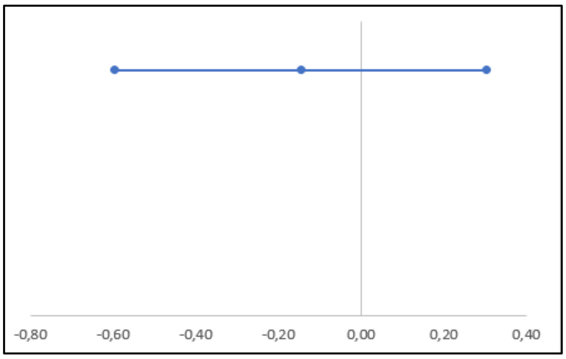


Figure 5 - Graph from Anthony Turner's (RSI at 30cm)

	N	Mean pre (SD)	Median pre	Mean post (SD)	Median post	Absolute Change (%)	TE	Qualitative
RSI (30 cm)	3	2,03 (0,67)	1,76	2,19 (0,61)	2,05	+ 7,88		↗ small

Figure 3 : This figure is extract from JASP's application. A Bayesian samples T-test was made, and it shows that there is a significant difference between both samples (pre- and post- values).

Figure 4 : The paired Hedges' *g* between Pre and Post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slope graph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 95% confidence interval is indicated by the ends of the vertical error bar.

Results: The paired Hedges' g for repeated measures against baseline between Pre and Post is 0.199 [95.0%CI 0.0978, 0.323]. The *P* value of the two-sided permutation t-test is 0.236, calculated for legacy purposes only. The effect sizes and CIs are reported above as: *effect size* [*CI width* *lower bound*; *upper bound*]

Figure 5 : This figure represents the effect protocol (-0,14 ; -0,59; 0,31) for the RSI test at 30cm.

The Hedges' g was calculated at 0,249878 with *statology.org*, which is considered as a small effect size.

Table 3 - Statistical analysis RSI at 50 cm (pre- and post- test)

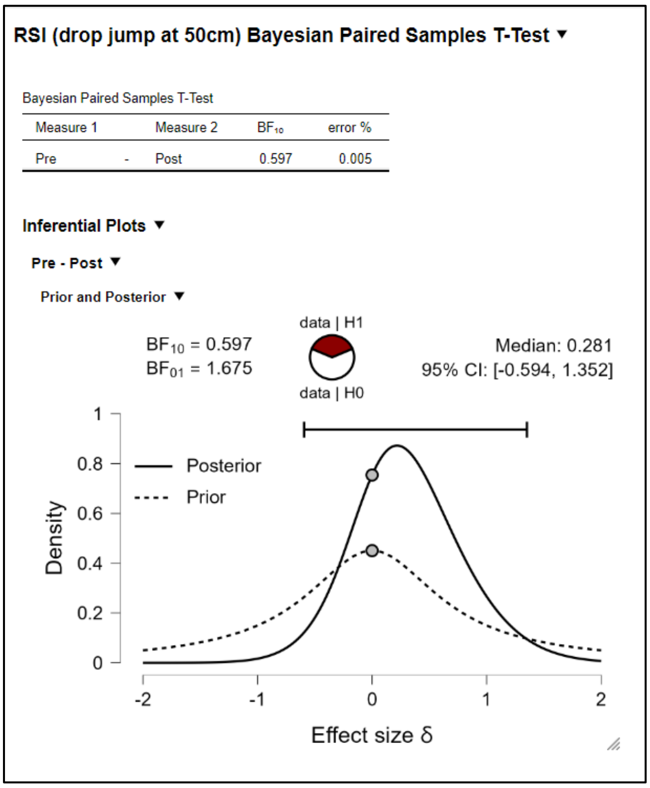


Figure 7 - Bayesian paired samples T-test (RSI at 50cm)

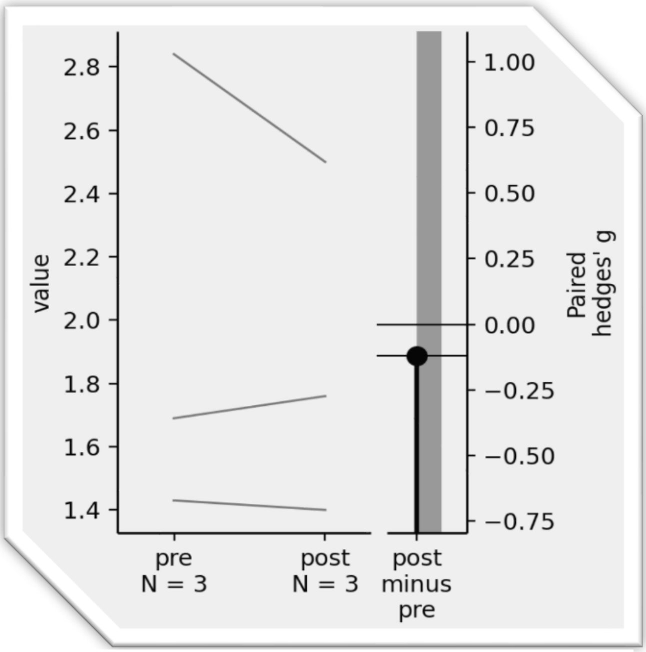


Figure 6 - Graph with individual evolutions and hedges' g (RSI at 50cm)

Hedges' g: 0.150965

"statology.org"

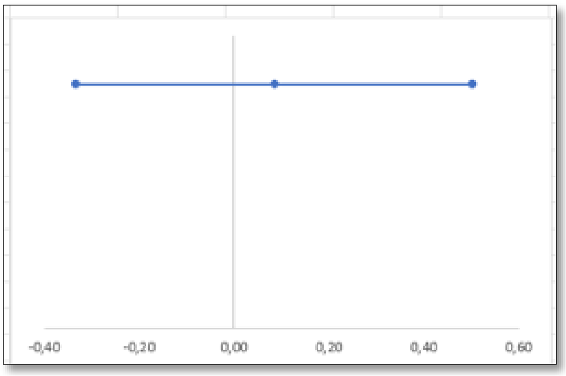


Figure 8 - Graph from Anthony Turner's (RSI at 50cm)

	N	Mean pre (SD)	Median pre	Mean post (SD)	Median post	Absolute Change (%)	TE	Qualitative
RSI (50 cm)	3	1,99 (0,77)	1,69	1,89 (0,56)	1,76	- 5,13		↘ very small

Figure 8 : This figure is extract from JASP's application. A Bayesian samples T-test was made, and it shows that the difference between both samples (pre- and post- values) is non-significant.

Figure 7 : The paired Hedges' *g* between pre and post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slope graph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 75% confidence interval is indicated by the ends of the vertical error bar.

Results: The paired Hedges' g for repeated measures against baseline between pre and post is -0.12 [75.0%CI -1.24e+14, -0.0953]. The *P* value of the two-sided permutation t-test is 0.508, calculated for legacy purposes only. The effect sizes and CIs are reported above as: *effect size* [*CI width lower bound*; *upper bound*]

Figure 6 : This figure represents the effect protocol (0,09 ; -0,33; 0,51) for the RSI test at 50cm.

The Hedges' g was calculated at 0,150965 with *statology.org*, which is considered as a very small effect size.

Table 4 - Statistical analysis RSI at 60 cm (pre- and post- test)

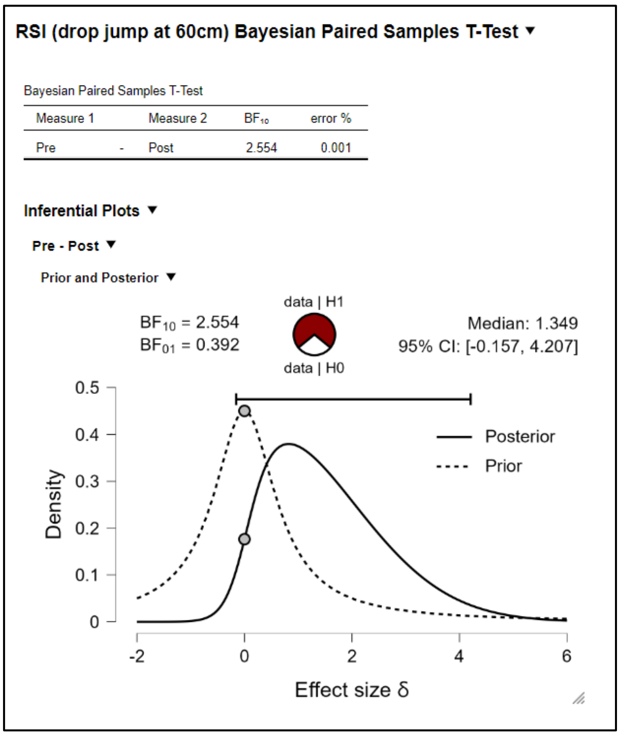


Figure 9 - Bayesian paired samples T-test (RSI at 60cm)

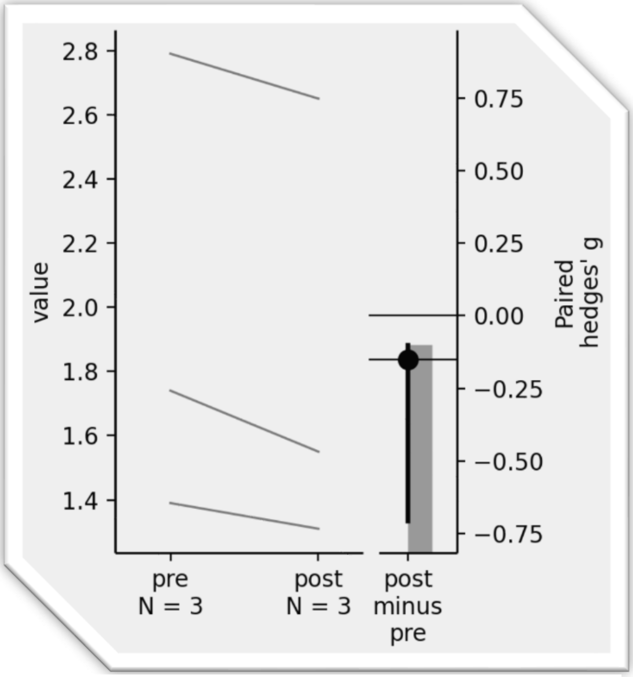


Figure 10 - Graph with individual evolutions and hedges' g (RSI at 60cm)

Hedges' g: **0.189398**

"statology.org"

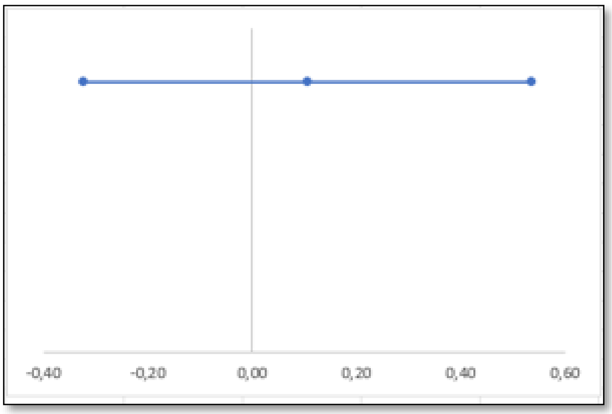


Figure 11- Graph from Anthony Turner's (RSI at 60cm)

	N	Mean pre (SD)	Median pre	Mean post (SD)	Median post	Absolute Change (%)	TE	Qualitative
RSI (60 cm)	3	1,97 (0,73)	1,74	1,84 (0,71)	1,55	- 6,60		↘ very small

Figure 9 : This figure is extract from JASP's application. A Bayesian samples T-test was made, and it shows that there is a significant difference between both samples (pre- and post- values).

Figure 10 : The paired Hedges' *g* between pre and post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slope graph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 90% confidence interval is indicated by the ends of the vertical error bar.

Results: The paired Hedges' g for repeated measures against baseline between pre and post is -0.151 [90.0%CI -0.706, -0.101]. The *P* value of the two-sided permutation t-test is 0.236, calculated for legacy purposes only. The effect sizes and CIs are reported above as: *effect size* [*CI width* *lower bound*; *upper bound*]

Figure 11 : This figure represents the effect protocol (0,11 ; -0,32; 0,54) for the RSI test at 60cm.

Table 5 - Statistical analysis COD planned (pre- and post- test)

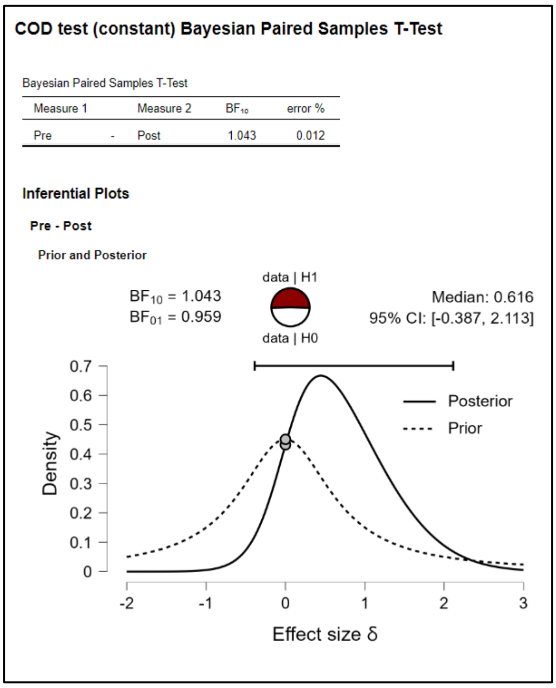


Figure 12 - Bayesian paired samples T-test (COD planned)

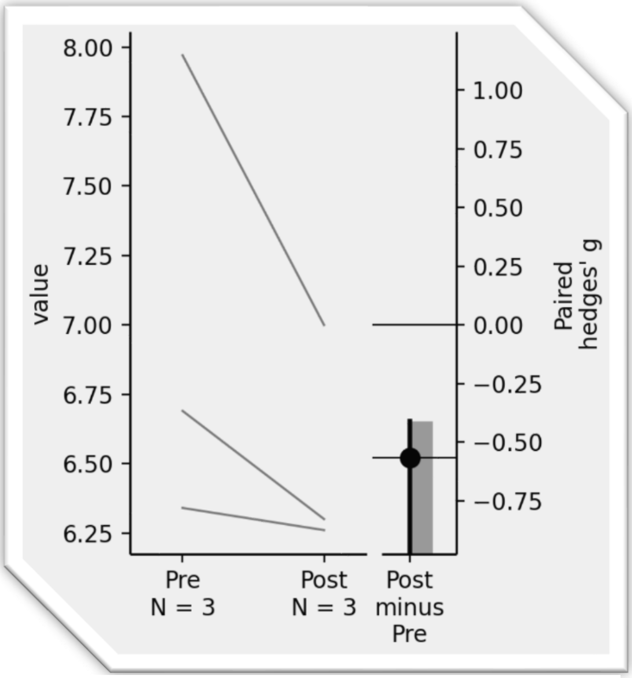


Figure 13 - Graph with individual evolutions and hedges' g (COD planned)

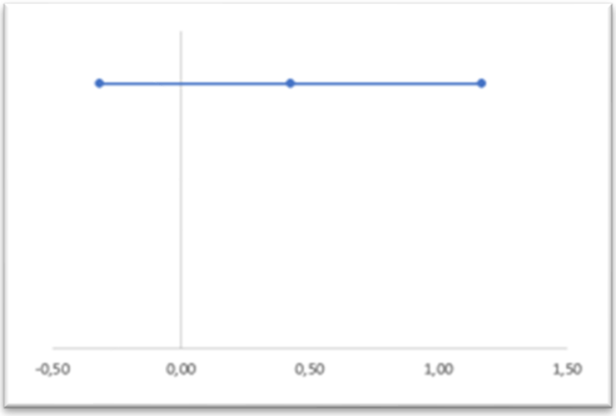


Figure 14 - Graph from Anthony Turner's (COD planned)

Hedges' g: 0.711795

"statology.org"

	N	Mean pre (SD)	Median pre	Mean post (SD)	Median post	Absolute Change (%)	TE	Qualitative
COD p	3	7,00 (0,86)	6,69	6,52 (0,42)	6,3	- 6,96		↗ medium

Figure 13 : This figure is extract from JASP's application. A Bayesian samples T-test was made, and it shows that there is a significant difference between both samples (pre- and post-values).

Figure 14 : The paired Hedges' *g* between Pre and Post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slope graph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 95% confidence interval is indicated by the ends of the vertical error bar. Results: The paired Hedges' g for repeated measures against baseline between Pre and Post is -0.568 [95.0%CI -1.59, -0.411]. The *P* value of the two-sided permutation t-test is 0.0, calculated for legacy purposes only. The effect sizes and CIs are reported above as: *effect size* [*CI width lower bound*; *upper bound*]

Figure 12 : This figure represents the effect protocol (0,43 ; -0,31; 1,17) for the COD test planned.

Table 6 - Statistical analysis COD reactive (pre- and post- test)

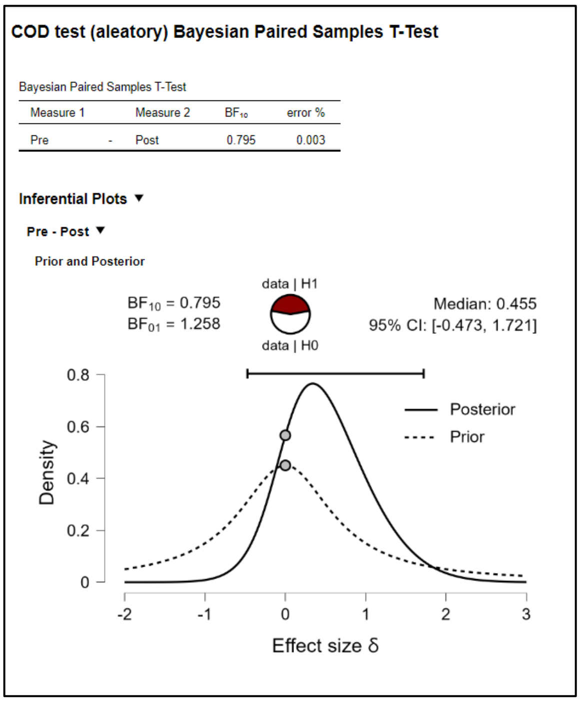


Figure 16 - Bayesian paired samples T-test (COD reactive)

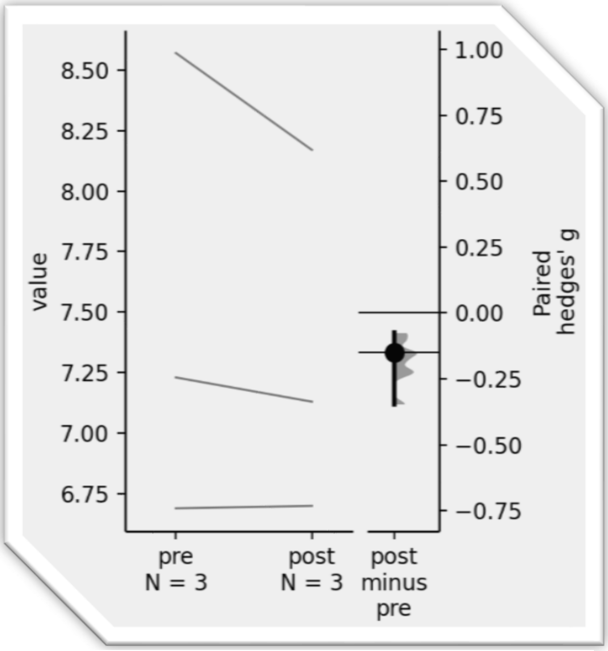


Figure 15 - Graph with individual evolutions and hedges' g (COD reactive)

Hedges' g: **0.188090**

"statology.org"

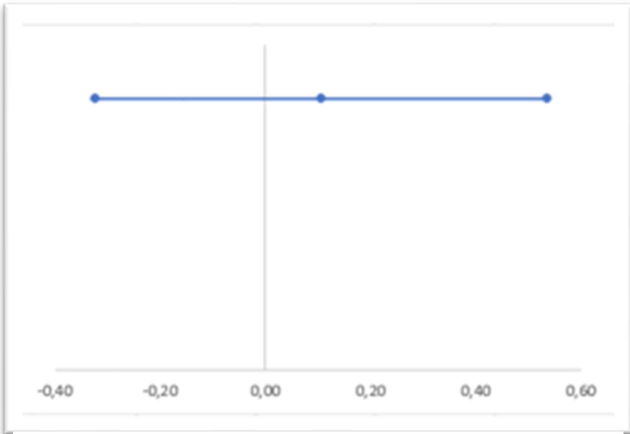


Figure 17 - Graph from Anthony Turner's (COD reactive)

	N	Mean pre (SD)	Median pre	Mean post (SD)	Median post	Absolute Change (%)	TE	Qualitative
COD r	3	7,50 (0,97)	7,23	7,33 (0,76)	7,13	- 2.37		↗very small

Figure 16 : This figure is extract from JASP's application. A Bayesian samples T-test was made, and it shows that the difference between both samples (pre- and post- values) is non-significant.

Figure 15 : The paired Hedges' *g* between pre and post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slope graph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 85% confidence interval is indicated by the ends of the vertical error bar.

Results: The paired Hedges' g for repeated measures against baseline between pre and post is -0.15 [85.0%CI -0.346, -0.0755]. The *P* value of the two-sided permutation t-test is 0.505, calculated for legacy purposes only. The effect sizes and CIs are reported above as: *effect size* [*CI width lower bound*; *upper bound*]

Figure 17 : This figure represents the effect protocol (0,43 ; -0,31; 1,17) for the COD test reactive.

Table 7 - Summary table of the results

(RSI = Reactive Strength Index; COD p = change of direction planned; COD r = change of direction reactive; SD = standard deviation ; TE = typical error; ↗ or ↘ = performance's augmentation or diminution *)*

	N	Mean pre (SD)	Mean post (SD)	Absolute Change (%)	TE	Qualitative
RSI (30 cm)	3	2,03 (0,67)	2,19 (0,61)	+ 7,88		↗ small
RSI (50 cm)	3	1,99 (0,75)	1,89 (0,56)	- 5,13		↘ very small
RSI (60 cm)	3	1,97 (0,73)	1,84 (0,71)	- 6,60		↘ very small
COD p	3	7,00 (0,86)	6,52 (0,42)	- 6,96		↗ medium
COD r	3	7,50 (0,97)	7,33 (0,76)	- 2,37		↗ very small

Discussion

The objective of the study was to assess the impact of plyometric training on tennis players' change of direction performance. The main result indicate that a plyometric training program such as the one presented in this study can lead to a significant improvement in change of direction performance, with a medium effect size. There was an absolute change of 7% faster for the change of direction test in the planned condition.

These conclusions suggest that incorporating plyometric exercises into the training program of tennis players may be beneficial for their ability to change direction quickly on the court.

In this study, regarding the reactive strength index (RSI) in condition of a drop jump at 30cm, a slight increase of 7.88% was observed. The comparison of this results with those of another study (Håvard Guldteig Rædergârd, 2020), where an increase of 16.8% was achieved. It is interesting to note that pre-test values in our study were significantly higher than those of the Hâvard's study. This observation leads us to hypothesize that our increase might be less significant than theirs due to our higher initial values. In fact, it is more difficult to improve a performance which was already high, than a worse one. This observation raises questions about the variations in results between different studies and highlights the importance of considering participants' initial conditions when interpreting results.

Regarding the results for the 50 and 60 cm RSIs, a slight decrease was observed in the participants' performance, with respective changes of 5.13% and 6.60%. This raises questions about the factors that could explain this decline. A plausible hypothesis is that additional sports activities practiced by participants outside the training protocol may have led to an accumulation of neuromuscular fatigue. This fatigue may have negatively influenced their performance in RSI. Furthermore, our results suggest that our training protocol may not be optimal for improving RSI at fairly high Drop Jump heights. This observation shows the importance of considering participants' additional activities when designing training programs and highlights the need for future research to elucidate the underlying mechanisms of these performance variations.

The results of the change of direction tests reveal a significant decrease in time of 6.96% in the planned conditions, indicating a notable improvement in performance with a medium effect size. This improvement might be attributed to the training protocol implemented, given that participants maintained their sports habits throughout the study. This suggests the effectiveness of the plyometric training program in improving change of direction abilities in a predictable environment.

In contrast, in *reactive* conditions, only a 2.37% decrease in time was observed, with a very small effect size. This finding suggests that while change of direction ability may play a role in this context, other factors such as information processing ability might be more determinant.

In conclusion, our results indicate that the implemented training protocol led to a significant improvement in change of direction performance in planned conditions among participants. However, improvements in reactive conditions are less significant, highlighting the predominant role of information processing ability in these situations. These results highlight the importance of designing specific training programs to improve both planned and reactive aspects of change of direction performance for tennis players.

The choice of the use of simple equipment was made, in order to make the training protocol accessible to all tennis clubs, thus promoting its generalization and application to a wide range of players. This ensures that the benefits of training can be leveraged by a larger number of practitioners, regardless of their financial resources or the equipment available in their club. However, it is important to note that the use of more sophisticated equipment could yield more precise results, which could be particularly beneficial for research studies or for high-level athletes seeking to optimize their performance to the fullest.

Furthermore, the question of recovery time is crucial for training effectiveness. Taking into account the other training sessions that each player may have individually outside the protocol, adequate management of recovery time could have a significant impact on physiological adaptations and performance gains.

In conclusion, while the use of simple equipment makes the training protocol accessible and applicable to a broad audience, integrating more sophisticated equipment and personalized recovery time management could enhance training effectiveness and maximize benefits for tennis players. This approach would achieve a balance between accessibility and precision in training program design.

Conclusion

In conclusion, this study demonstrates that plyometric training leads to a significant improvement in change of direction performance. At the beginning of the protocol, the hypothesis was that plyometric training could be considered relevant. The results show that when subjects regularly perform plyometric exercises and are physically in good conditions, the gains in change of direction under both planned and reactive conditions are substantial. Although, even if results for the RSI tests at 50 and 60 cm don’t show an amelioration of the performance, for the RSI at 30 cm there was a significative one. Regarding the design of plyometric training, a period of 5 weeks, with 2 training sessions per week, moderate to high intensity, and 66 jumps per session, with 72-hour rest intervals, appears to promote improvements in change of direction.

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Table des tables

Table des figures

Annexes

I. Details of training sessions

Session 19/03	Series	Repetitions	Rests
Unilateral CMJ	5	1 with each leg	1min30
Drop jump	10	1	1min
Unilateral hurdle jump	5	3 with each leg	2 min
Bilateral Hurdle jump	4	3	1 min 30
skate jump	3	6 with each leg	1 min 30

Session 22/03	Series	Repetitions	Rests
Drop Jump	4	3	20sec
Unilateral CMJ	6	1 with each leg	1min
Bilateral Hurdle jump	6	3	1min
Unilateral hurdle jump	4	3 with each leg	2min
skate jump	3	6 with each leg	1 min 30

Session 26/03	Series	Repetitions	Rests
skate jump	4	4 with each leg	1 min 30
Bilateral Hurdle jump	4	6	20sec
Unilateral hurdle jump	4	3 with each leg	2 min
Drop jump	8	1	1min
Unilateral CMJ	6	6 with each leg	1min30

Session 29/03	Series	Repetitions	Rests
Unilateral hurdle jump	4	3 with each leg	1min30
Bilateral Hurdle jump	4	3 with each leg	1min
skate jump	3	8 with each leg	2min
Unilateral CMJ	6	1 with each leg	1min30
Drop jump	8	1	1min

Session 02/04	Series	Repetitions	Rests
Unilateral CMJ	5	1 with each leg	1min30
Drop jump	10	1	1min
Unilateral hurdle jump	5	3 with each leg	2 min
Bilateral Hurdle jump	4	3	1 min 30
skate jump	3	6 with each leg	1 min 30

Session 05/04	Series	Repetitions	Rests
Drop Jump	4	3	20sec
Unilateral CMJ	6	1 with each leg	1min
Bilateral Hurdle jump	6	3	1min
Unilateral hurdle jump	4	3 with each leg	2min
skate jump	3	6 with each leg	1 min 30

Session 09/04	Series	Repetitions	Rests
skate jump	4	4 with each leg	1 min 30
Bilateral Hurdle jump	4	6	20sec
Unilateral hurdle jump	4	3 with each leg	2 min
Drop jump	8	1	1min
Unilateral CMJ	6	6 with each leg	1min30

II. Report of monitoring training load

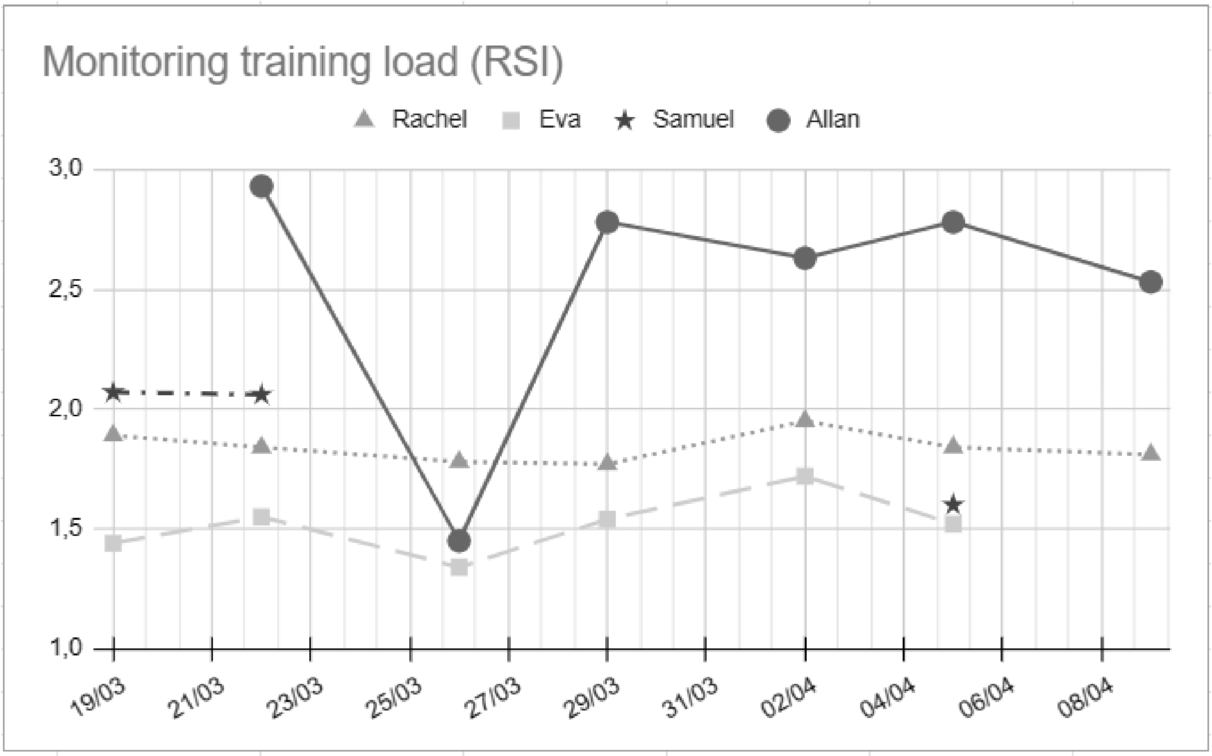


Figure 18 - Graph of monitoring training load

III. Results

a) RSI 30cm

RSI (drop jump at 30cm) Bayesian Paired Samples T-Test ▾

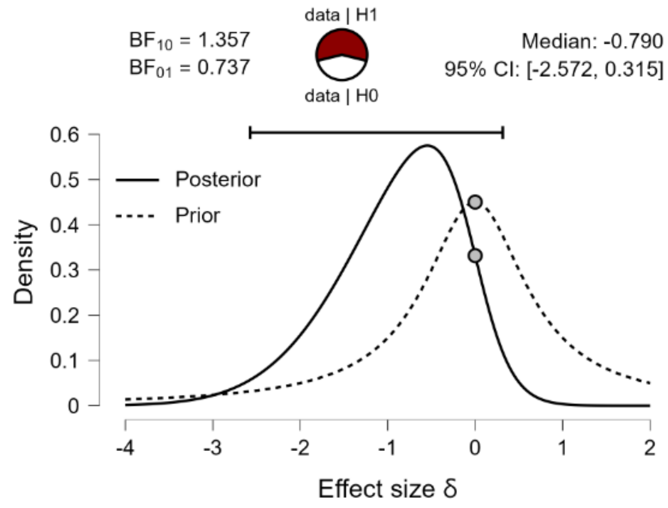
Bayesian Paired Samples T-Test

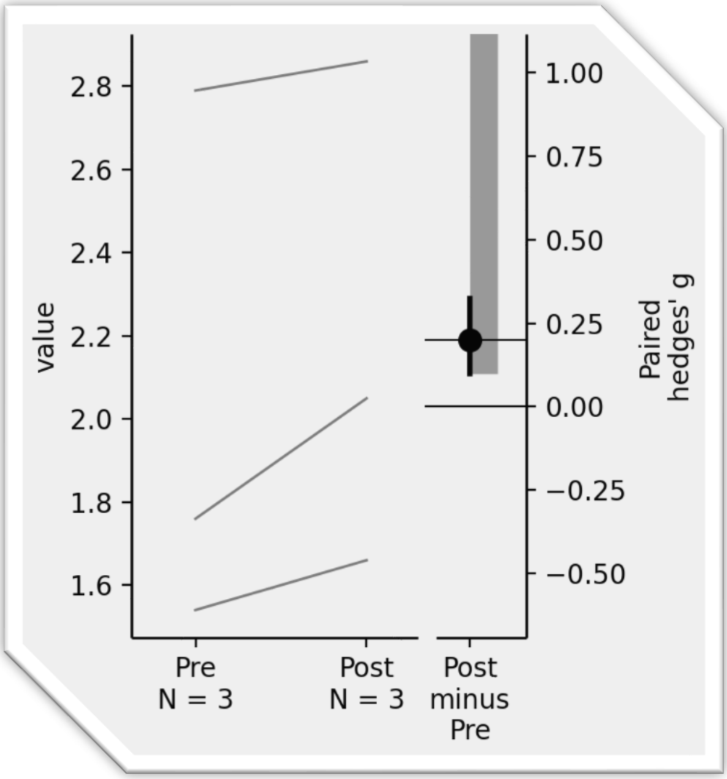
Measure 1		Measure 2	BF_{10}	error %
Pre	-	Post	1.357	0.031

Inferential Plots

Pre - Post

Prior and Posterior





Hedges' g: 0.249878

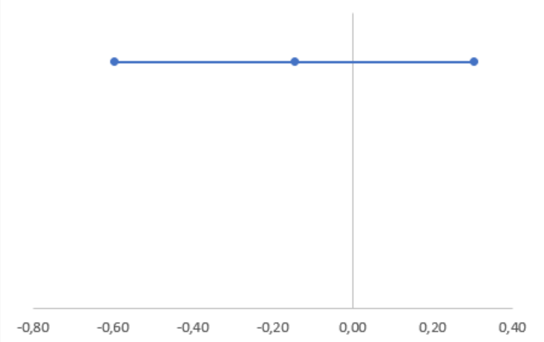
"statology.org"

Suggested Figure Legend:
The paired Hedges' *g* between Pre and Post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slope graph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 95% confidence interval is indicated by the ends of the vertical error bar.

Results:
The paired Hedges' g for repeated measures against baseline
between Pre and Post is 0.199 [95.0%CI 0.0978, 0.323].
The *P* value of the two-sided permutation t-test is 0.236, calculated for legacy purposes only.

The effect sizes and CIs are reported above as: *effect size* [*CI width lower bound*; *upper bound*]

Comparison	ES, LL, UL	order
	-0,14	1
Pre vs. post	-0,59	1
	0,31	1



We could say something along the lines of:

Pre *vs.* Post: we found an inscrease from small to larger jump heights compared to pre training (*g* = 0.81, 90% CI, 0.23 – 1.40)

b) RSI 50cm

RSI (drop jump at 50cm) Bayesian Paired Samples T-Test ▼

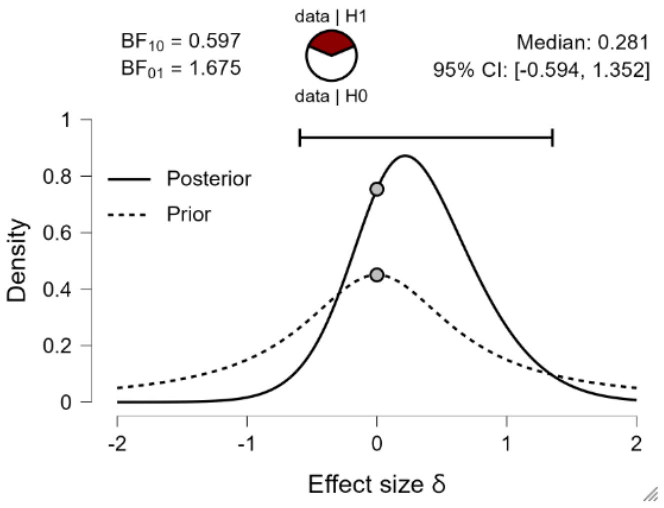
Bayesian Paired Samples T-Test

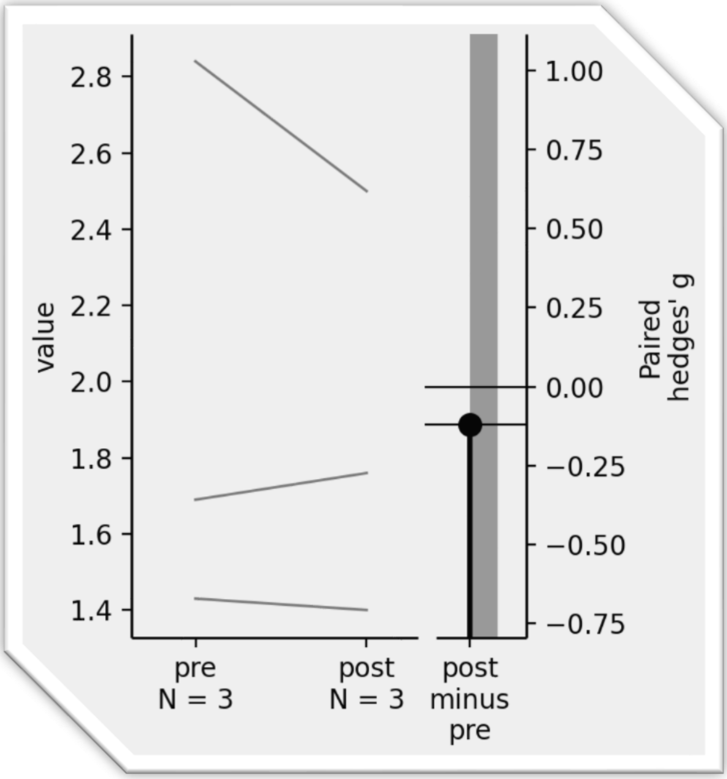
Measure 1		Measure 2	BF_{10}	error %
Pre	-	Post	0.597	0.005

Inferential Plots ▼

Pre - Post ▼

Prior and Posterior ▼





Suggested Figure Legend:
The paired Hedges' *g* between pre and post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slopegraph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 75% confidence interval is indicated by the ends of the vertical error bar.

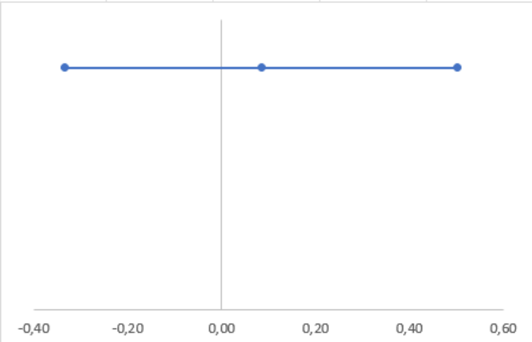
Hedges' g: **0.150965**

"statology.org"

Results:
The paired Hedges' g for repeated measures against baseline
between pre and post is -0.12 [75.0%CI -1.24e+14, -0.0953].
The *P* value of the two-sided permutation t-test is 0.508, calculated for legacy purposes only.

The effect sizes and CIs are reported above as: *effect size* [*CI width lower bound*; *upper bound*]

Comparison	ES, LL, UL	order
	0,09	1
Pre vs. post	-0,33	1
	0,51	1



We could say something along the lines of:

Pre *vs.* Post: we found an inscrease from small to larger jump heights compared to pre training (*g* = 0.81, 90% CI, 0.23 – 1.40)

c) RSI 60cm

RSI (drop jump at 60cm) Bayesian Paired Samples T-Test ▼

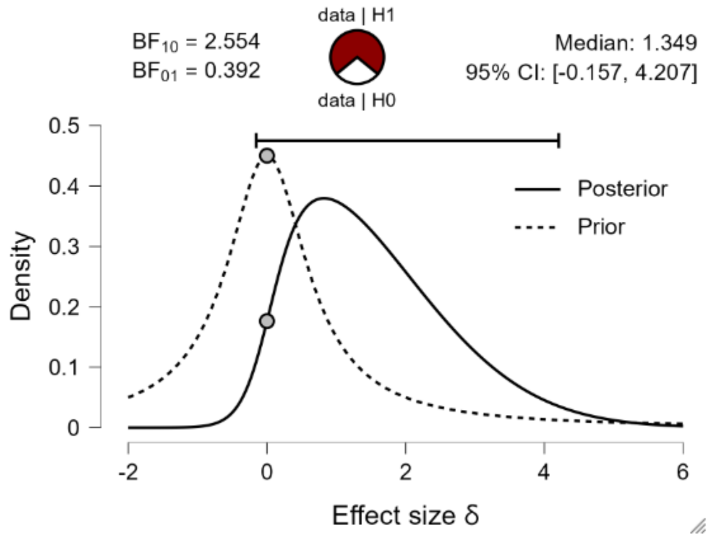
Bayesian Paired Samples T-Test

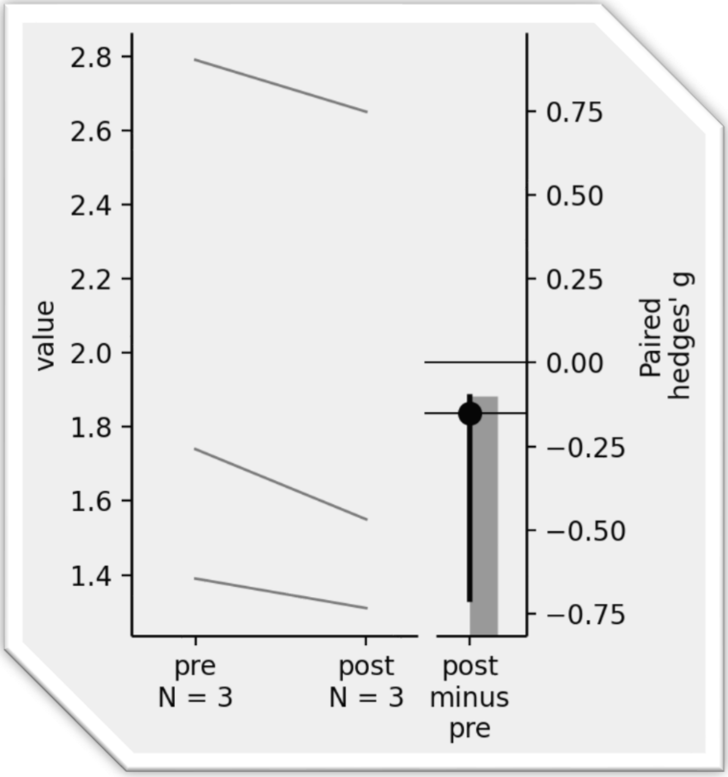
Measure 1		Measure 2	BF_{10}	error %
Pre	-	Post	2.554	0.001

Inferential Plots ▼

Pre - Post ▼

Prior and Posterior ▼





Suggested Figure Legend:
The paired Hedges' *g* between pre and post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slopegraph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 90% confidence interval is indicated by the ends of the vertical error bar.

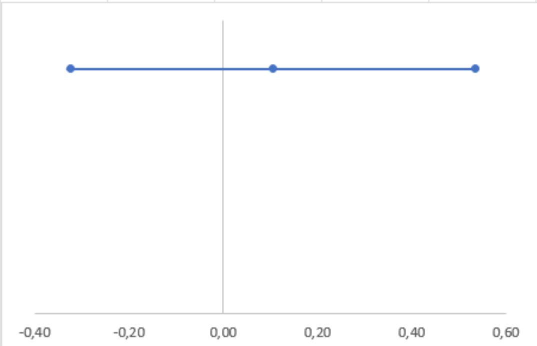
Hedges' g: **0.189398**

"statology.org"

Results:
The paired Hedges' g for repeated measures against baseline
between pre and post is -0.151 [90.0%CI -0.706, -0.101].
The *P* value of the two-sided permutation t-test is 0.236, calculated for legacy purposes only.

The effect sizes and CIs are reported above as: *effect size* [*CI width* *lower bound*; *upper bound*]

Comparison	ES, LL, UL	order
	0,11	1
Pre vs. post	-0,32	1
	0,54	1



We could say something along the lines of:

Pre vs. Post: we found an inscrease from small to larger jump heights compared to pre training (*g* = 0.81, 90% CI, 0.23 – 1.40)

d) COD Planned

COD test (constant) Bayesian Paired Samples T-Test

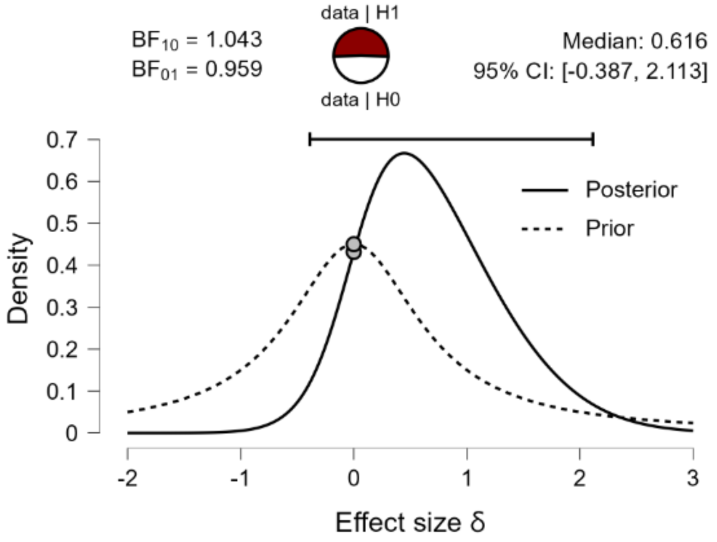
Bayesian Paired Samples T-Test

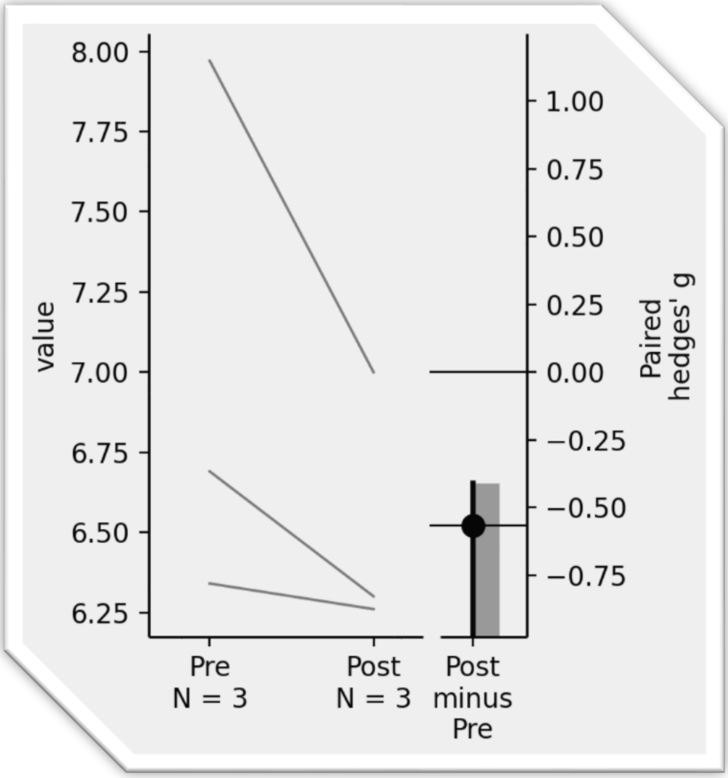
Measure 1		Measure 2	BF_{10}	error %
Pre	-	Post	1.043	0.012

Inferential Plots

Pre - Post

Prior and Posterior





Suggested Figure Legend:

The paired Hedges' *g* between Pre and Post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slopegraph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 95% confidence interval is indicated by the ends of the vertical error bar.

Hedges' g: **0.711795**

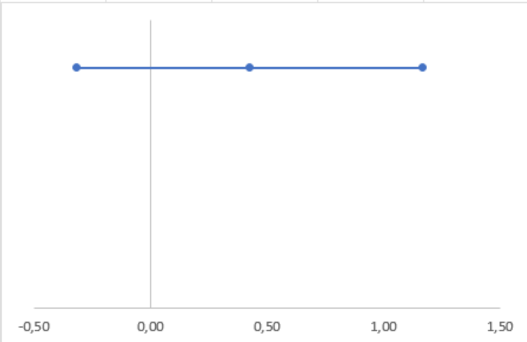
"statology.org"

Results:

The paired Hedges' g for repeated measures against baseline
between Pre and Post is -0.568 [95.0%CI -1.59, -0.411].
The *P* value of the two-sided permutation t-test is 0.0, calculated for legacy purposes only.

The effect sizes and CIs are reported above as: *effect size* [*CI width lower bound*; *upper bound*]

Comparison	ES, LL, UL	order
	0,43	1
Pre vs. post	-0,31	1
	1,17	1



We could say something along the lines of:

Pre *vs.* Post: we found an inscrease from small to larger jump heights compared to pre training (*g* = 0.81, 90% CI, 0.23 – 1.40)

e) COD Reactive

COD test (aleatory) Bayesian Paired Samples T-Test

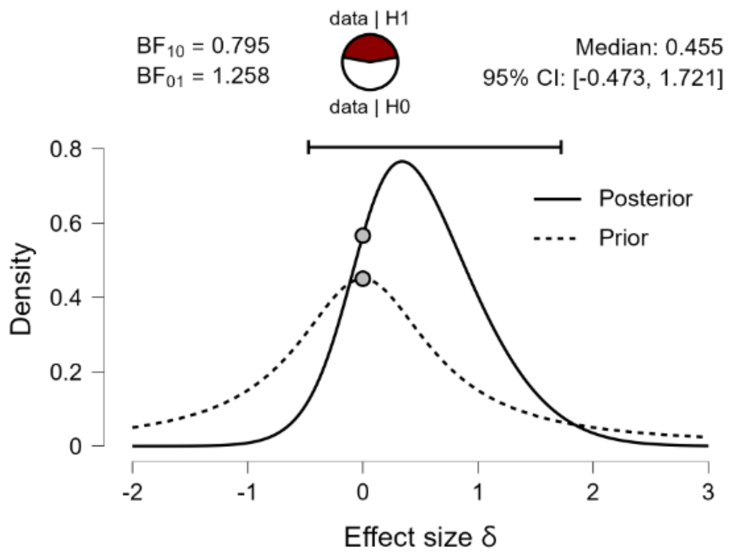
Bayesian Paired Samples T-Test

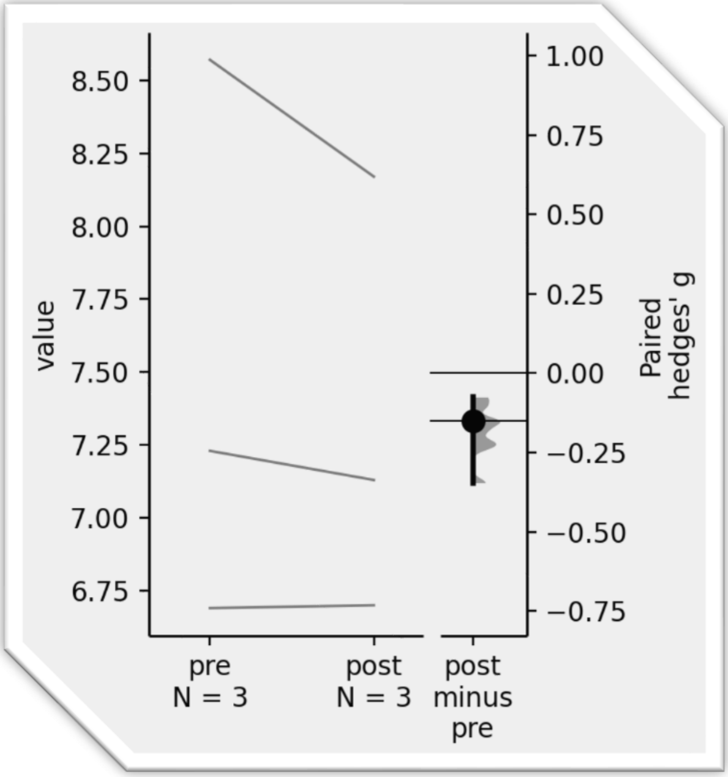
Measure 1		Measure 2	BF_{10}	error %
Pre	-	Post	0.795	0.003

Inferential Plots ▼

Pre - Post ▼

Prior and Posterior





Hedges' g: **0.188090**

"statology.org"

Suggested Figure Legend:

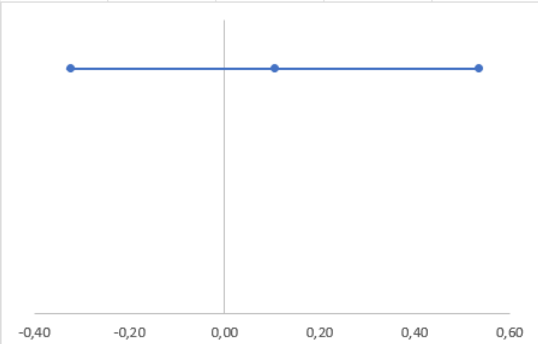
The paired Hedges' *g* between pre and post is shown in the above Gardner-Altman estimation plot. Both groups are plotted on the left axes as a slopegraph: each paired set of observations is connected by a line. The paired mean difference is plotted on a floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 85% confidence interval is indicated by the ends of the vertical error bar.

Results:

The paired Hedges' g for repeated measures against baseline
between pre and post is -0.15 [85.0%CI -0.346, -0.0755].
The *P* value of the two-sided permutation t-test is 0.505, calculated for legacy purposes only.

The effect sizes and CIs are reported above as: *effect size* [*CI width lower bound*; *upper bound*]

Comparison	ES, LL, UL	order
	0,11	1
Pre vs. post	-0,32	1
	0,54	1



We could say something along the lines of:

Pre *vs.* Post: we found an inscrease from small to larger jump heights compared to pre training (*g* = 0.81, 90% CI, 0.23 – 1.40)

Testing Speed and Agility in Elite Tennis Players

Karl Cooke, PhD,[1] Ann Quinn, PhD,[2] and Narelle Sibte, BAppSc[3]
[1]National Tennis Centre, Lawn Tennis Association, Roehampton, London, United Kingdom; [2]Quintessential Difference Ltd., Mayfair, London, United Kingdom; and [3]Tennis Australia, Private Bag, Richmond South, Victoria, Australia

Australia). Tennis players rarely run more than 3 m to a ball (10,5), and thus, the 3 light gates were placed 3 m from the center of the baseline. The middle gate is placed directly along the centerline of the court, and the gates to the left and right are placed along the lines from the center of the baseline to the intersection of the service line and the singles side line on the left and right. Each gate is 1 m wide, and the tripods are placed along a line perpendicular to the line used to measure the 3-m distance from the baseline.

The players are instructed to perform 3 efforts of the planned and then the reactive agility conditions. Each effort requires the player to start behind the yellow contact mat, which is placed behind the baseline. The contact mat acts as a switch turning on the light on the selected gate. The player is asked to initiate the effort by split stepping on to the mat and to move as quickly as possible to the gate in which the light appears. On reaching the gate, the player is instructed to step over a line marker placed 30 cm beyond the gate. This helps to ensure that the trunk is consistently used to break the light gate. The player then returns to the contact mat and repeats this for a total of 3 gates.

Players are instructed to move as they would during a tennis match, as the testers did not wish to change existing natural movement patterns of the players. The total time taken to complete the movement to 3 gates is used for evaluation. The planned condition is programmed, so that the gates are illuminated in order from right to left (right, center, left; the player is informed of this in advance).

In contrast, the reactive condition is a sequence of 3 gates, which are randomized and may include returning to the same gate 2 or even 3 times. The best of the 3 times for each condition is taken, and the difference between planned and reactive conditions is used as a measure of reaction time. To ensure optimal times for each player, there should be no less than 60-second recovery between trials as previously suggested by other authors (11).

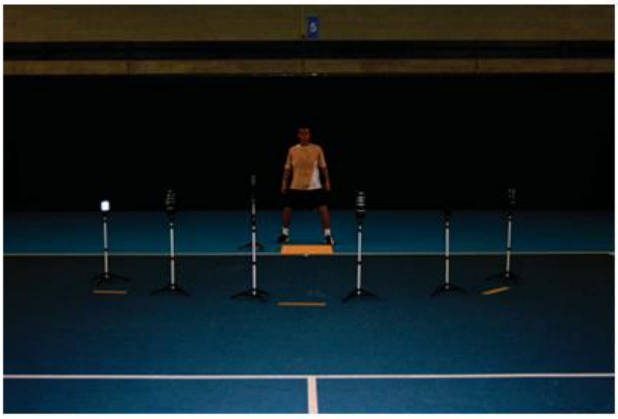


Figure. Planned and reactive agility test setup.

Using the Reactive Strength Index Modified to Evaluate Plyometric Performance

William P. Ebben[1] and Erich J. Petushek[2]

[1]Department of Physical Therapy, Program in Exercise Science, Strength and Conditioning Research Laboratory, Marquette University, Milwaukee, Wisconsin; and [2]Department of Health, Physical Education and Recreation, Northern Michigan University, Marquette, Michigan

Abstract

Ebben, WP and Petushek, EJ. Using the reactive strength index modified to evaluate plyometric performance. *J Strength Cond Res* 24(8): 1983–1987, 2010—The ability to develop force quickly is a requisite ability in most sports. The reactive strength a highly reliable method of assessing the explosiveness developed during a variety of plyometric exercises.

Key Words countermovement jump, instrumentation, athlete testing, power, reliability

Average measures
0.95
0.95
0.96
0.96
0.96

Discussion

This study introduces the concept of the RSI_{mod} to the literature, demonstrates its high level of reliability for a variety of plyometric exercises (9), and shows that there are differences in RSI_{mod} for all of the plyometric exercises assessed. Thus, plyometric exercises can be prescribed and progressed in a program using this measure of force and the time it takes to develop it. This study also demonstrates no gender differences in the ranking of plyometric exercise with respect to the RSI_{mod}. Thus, the RSI_{mod} can be used as a potentially measure of explosiveness and the ability to quickly develop maximal force, which is believed to be important in athletics (18,19).

The reliability of the RSI_{mod} is similar to the RSI based on a comparison of current results and previously reported ICC values (7). The RSI is typically calculated for the DJ, and the value obtained may depend on the DJ box height (12). The RSI_{mod} is not confounded by box height choice such as is the case with the DJ, and an athlete's performance of the eccentric and concentric phases of the SSC is likely to be fairly uniform for most plyometric exercises.

Article

Effects of Strength vs. Plyometric Training on Change of Direction Performance in Experienced Soccer Players

5. Conclusions

The development of change of direction ability has become more specific. This research shows that there is some task-specific adaptation in COD depending on the angle of direction change and approaching velocity to the COD maneuver. In summary, both the strength and the plyometric training program, in particular, are useful for developing COD ability that requires angles of directional change of ≥90° and ≥135°, respectively, in mature male soccer players in six weeks. The plyometric training program can effectively be used by players that want to surpass or respond to opponents in anticipated situations where the angle of direction change is relatively sharp (>90°). Considering the limited time for implementing physical conditioning, in addition to regular soccer practice in most soccer environments, the current plyometric training program can be advantageous in improving CODs at maximal intensity. However, strength and conditioning coaches must carefully apply the training program based on the individual player, as previous work [15] has shown that a minimum level of maximal strength in the lower limbs is necessary for plyometric training to have an effect upon COD ability.

Running Activity Profile of Adolescent Tennis Players During Match Play

Matthias W. Hoppe, Christian Baumgart, and Jutta Bornefeld
University of Wuppertal

Billy Sperlich
University of Würzburg

Jürgen Freiwald
University of Wuppertal

Hans-Christer Holmberg
Mid Sweden University

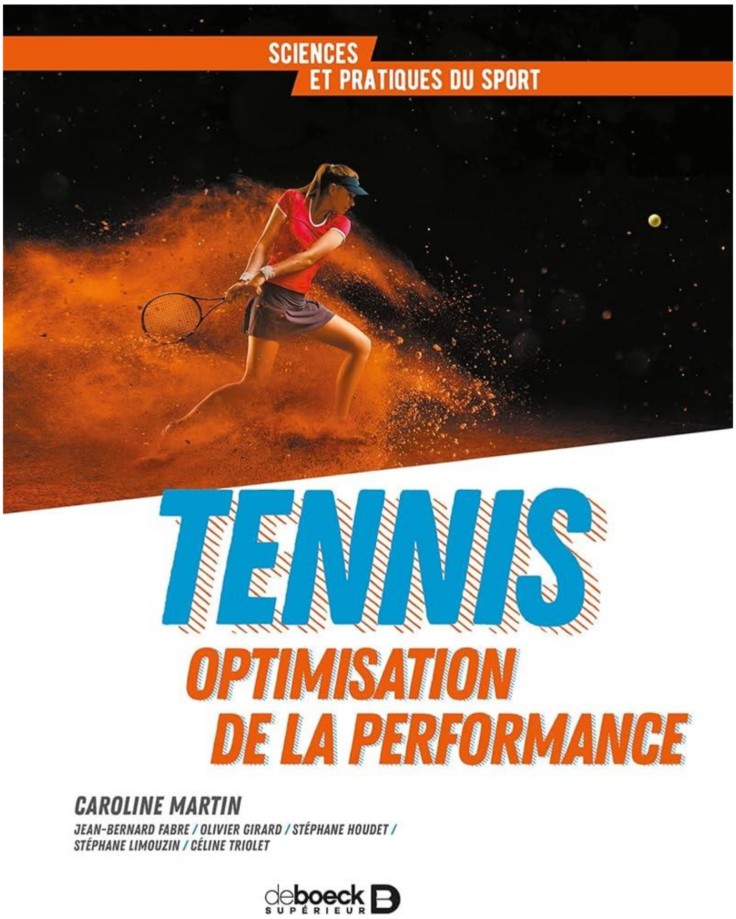
during match play with respect to velocity, acceleration, and deceleration; (2) to characterize changes in these activities during the course of a match; and (3) to identify potential differences between winners and losers. Such knowledge is essential for designing efficient and productive training programs for adolescent tennis players early in their development. The major findings were as follows: (1) The running activities of adolescent tennis players were characterized primarily by high accelerations and decelerations, but low velocities; (2) the pattern of these running activities did not change during the course of a match; and (3) the running activities of winners and losers did not differ.

The total match time (81.2 ± 14.6 min) observed was similar to the typical average duration of a tennis match in adult players (ie, a total playing time of approximately 90 min; 30). However, the total distance covered (3362 ± 869 m) differs from those in two earlier reports (18,36). In one of these, during 90 min of simulated match play on clay and hart courts, adolescent tennis players ran 1447 ± 143 m and 1199 ± 168 m, respectively (36). And in the other, during 60 min of simulated match play on clay courts, advanced and recreational adult tennis players ran 3569 ± 532 m and 3174 ± 226 m, respectively (18).

The main explanation for these discrepancies may be methodological. In the present case and in one of those earlier studies (18), the distances covered when walking to pick up balls was included, whereas the other investigation (36) only included distances covered when the ball was in play. Since walking to pick up the ball contributes fundamentally to the match activities of adolescent tennis players, representing a type of active recovery, this information is important. In addition, various factors (eg, number of sets played, court surfaces, type of ball used, and temperature) and characteristics of the players (eg, age, sex, nutritional status, and physical, tactical/technical, and psychological characteristics) can influence match duration and intensity (17,19) and, consequently, the total distance covered profoundly.

Our adolescent tennis players attained a peak velocity of 4.4 ± 0.8 $m \cdot s^{-1}$ and covered 2.4% of the total distance at velocity categories ^{3} 3 $m \cdot s^{-1}$. These observations are in-line with a previous velocity analysis of advanced and recreational adult tennis players (18). However, our players executed three times as many running activities involving high acceleration (0.6 ± 0.2 $n \cdot min^{-1}$) and deceleration (0.6 ± 0.2 $n \cdot min^{-1}$) than those involving high velocity (0.2 ± 0.1 $n \cdot min^{-1}$) per min of match play (Figure 1). To our knowledge, this is the first demonstration that the running activities of adolescent tennis players are characterized primarily by high accelerations and decelerations but low velocities, a situation reflecting the intermittent play involved in tennis, which does not allow high velocities to be reached. Accordingly, analysis of the running activities of adolescent tennis players during match play should include measurement of velocity, acceleration, and deceleration. Failure to include acceleration and deceleration may result in underestimation of the high-intensity running activities performed (6,16).

A unique observation was that the pattern of running activities of adolescent tennis players did not change (P ^{3} .13, $d \leq 0.39$) as the match proceeded (Table 2). This finding is supported by two previous reports in which sprint and jump performance were assessed with separate standardized test protocols during several breaks in tennis match play (21,33). In one of these, the 4.66-m linear sprint times of internationally ranked adult tennis players following the 4th, 8th, 12th, and 16th game of a



Auteurs	Surface	Sexe	Niveau	FC moyenne (bpm)
		Juniors (< 18 ans)		
Hoppe *et al.*, 2014	TB	H	Club	159 ± 112
Girard et Millet, 2004	TB Dur	H	Club	182 ± 112 173 ± 17
Fernandez-Fernandez *et al.*, 2007	TB	F	International	161 ± 5
Ridhwan *et al.*, 2010	Dur	H	National	154 ± 15
		Adultes (18-35 ans)		
Dansou *et al.*, 2001	Dur	H	Régional et national	141 ± 5
Murias *et al.*, 2007	TB Dur	H	National	143 ± 22 135 ± 21
Bergeron *et al.*, 1991	Dur	H	National	144 ± 13
Hornery *et al.*, 2007	Dur TB	H	Professionnel	152 ± 15 146 ± 19
Smekal *et al.*, 2001	TB	H	National	151 ± 19
		Vétérans (> 35 ans)		
Ferrauti *et al.*, 2001a	Dur	H F	National National	143 ± 13 142 ± 19
Fernandez-Fernandez *et al.*, 2009b	TB	H	Compétition Loisir	144 ± 12 150 ± 8

The Effects of a 6-Week Plyometric Training Program on Agility

Michael G. Miller,[1,✉,*] Jeremy J. Herniman,[1,*] Mark D. Ricard,[2,*] Christopher C. Cheatham,[1,*] and Timothy J. Michael[1,*]

Introduction

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Plyometrics are training techniques used by athletes in all types of sports to increase strength and explosiveness (Chu, 1998). Plyometrics consists of a rapid stretching of a muscle (eccentric action) immediately followed by a concentric or shortening action of the same muscle and connective tissue (Baechle and Earle, 2000). The stored elastic energy within the muscle is used to produce more force than can be provided by a concentric action alone (Asmussen and Bonde-Peterson, 1974; Cavagna, 1977; Komi, 1992; Miller, et al., 2002; Pfeiffer, 1999; Wathen, 1993). Researchers have shown that plyometric training, when used with a periodized strength-training program, can contribute to improvements in vertical jump performance, acceleration, leg strength, muscular power, increased joint awareness, and overall proprioception (Adams, et al., 1992; Anderst et al., 1994; Bebi et al., 1987; Bobbert, 1990; Brown et al., 1986; Clutch et al., 1983; Harrison and Gaffney, 2001; Hennessy and Kilty, 2001; Hewett et al., 1996; Holcomb et al., 1996; Miller et al., 2002; Paasuke et al., 2001; Potteiger et al., 1999; Wilson et al., 1993).

Plyometric drills usually involve stopping, starting, and changing directions in an explosive manner. These movements are components that can assist in developing agility (Craig, 2004; Miller et al., 2001; Parsons et al., 1998; Yap et al., 2000; Young et al., 2001). Agility is the ability to maintain or control body position while quickly changing direction during a series of movements (Twist and Benickly, 1995). Agility training is thought to be a re- enforcement of motor programming through neuromuscular conditioning and neural adaptation of muscle spindles, golgi-tendon organs, and joint proprioceptors (Barnes and Attaway, 1996; Craig, 2004, Potteiger et al., 1999). By enhancing balance and control of body positions during movement, agility theoretically should improve.

It has been suggested that increases in power and efficiency due to plyometrics may increase agility training objectives (Stone and O'Bryant, 1984) and plyometric activities have been used in sports such as football, tennis, soccer or other sporting events that agility may be useful for their athletes (Parsons and Jones, 1998; Renfro, 1999; Robinson and Owens, 2004; Roper, 1998; Yap and Brown, 2000). Although plyometric training has been shown to increase performance variables, little scientific information is available to determine if plyometric training actually enhances agility. Therefore, the purpose of this study was to determine the effects of a 6-week plyometric training program on agility.

Conclusions

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The results from our study are very encouraging and demonstrate the benefits plyometric training can have on agility. Not only can athletes use plyometrics to break the monotony of training, but they can also improve their strength and explosiveness while working to become more agile. In addition, our results support that improvements in agility can occur in as little as 6 weeks of plyometric training which can be useful during the last preparatory phase before in-season competition for athletes.

4nv

Match Characteristics of Professional Singles Tennis

SARAH MORANTE AND JOHN BROTHERHOOD

*Table 1 Data (mean ± SD) comparing males and females from 39 matches (78 sets of observations) at the 2005 Australian Open and Wimbledon Championships, n = number of observations. * Male = best of 5 sets, female - best of 3 sets.*

Variable	Australian Open		Wimbledon		Tournament (P)	Gender (P)	Interaction (P)
	Male(n=12)	Female (n=9)	Male(n=12)	Female (n=6)			
Match duration (min)*	154.2 ±47.2	113.5 ±33.2	137.0 ±69.1	65.3 ±15.9	0.08	0.004	0.398
Game duration (s)	178.6 + 26.2	183.8 ±29.4	159.0 ±22.3	189.8 ±31.0	0.479	0.067	0.189
Point duration (s)	6.4 ± 1.4	7.0 ±1.3	5.2 ±0.8	5.6 ± 0.6	0.01	0.186	0.849
Effective playing time (%)	17.5 + 2.4	20.2 ±2.1	20.5 ±2.1	21.1 ±1.6	0.027	0.064	0.235
Stroke frequency (strokes/min)	44.0 ± 0.6	42.2 ±3.1	45.1 ±1.3	44.1 ±1.0	0.01	0.013	0.483

Table 2 Publislied tennis analyses

Study	Match Duration (min)	Point Duration (s)	Effective Playing Time (%)	Work to Rest Ratio	Stroke Frequency (strokes/min)
Present study	M=145.6+58.5 F= 97.9±37.3	M=5.9±1.3 F= 6.4 ±1.2	M=19.0±3.0 F=19.9±2.3	M = 1:4.4±0.8 F = 1:4.1 ±0.6	M = 44.5+1.2 F = 42.9±2.3
Smekal etal.[1]-[4]		M= 6.4 ±4.1	M=16.3±6.6	M = 1 : 3.4	M = 42.6+9.6
Elliott et al.[3]	M=60	M=10.0±1.6	M=26.5±3.5	M = 1 :2.9	
Christmass et al.[6]	M=90	M=10.2±0.3	M=23.3±1.4	M = 1 :1.8	
Reilly & Palmer[7]		M=5.3±1.05	M=27.9±3.9	M = 1 :3.1	
Chandler[8]	M=294 F=101	M=12.2 F=10.8		M = 1 :3.4 F = 1 :2.7	
O'Donoghue and Ingram[5]		M+F = 6.3±1.8			

A practical method of estimating energy expenditure during tennis play

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Novas, A, M, P, Rowbottom & D, G, Jenkins, D, G, (2003). A practical method of estimating energy expenditure during tennis play. *Journal of Science and Medicine in Sport 6 (1): 40-50.*

Energy expenditure values obtained for the 60-min of match play were 1853±253 kJ from direct measurement of VO_2 (total VO_2 during the match plus O_2 debt during recovery). Post-match recovery ranged between 2 and 4 minutes. Energy expenditure values predicted were 1945±290 $kJ.h^{-1}$ and 2289±891 $kJ.h^{-1}$ respectively from RPE and HR regression equations

Activity patterns, blood lactate concentrations and ratings of perceived exertion during a professional singles tennis tournament

Alberto Mendez-Villanueva, Jaime Fernandez-Fernandez, David Bishop, Benjamin Fernandez-Garcia, Nicolas Terrados

Br J Sports Med 2007;**41**:296–300. doi: 10.1136/bjsm.2006.030536

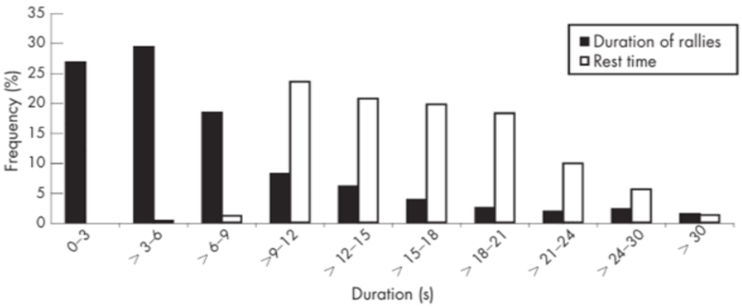

Figure 1 Mean percentage of playing time intervals (duration of rallies) and recovery (rest time between rallies).

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Agility literature review: Classifications, training and testing

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Defining agility

At present, there is no consensus among the sports science community for a clear definition of agility. Agility has classically been defined as simply the ability to change direction rapidly (Bloomfield, Ackland, & Elliot, 1994; Clarke, 1959; Mathews, 1973), but also the ability to change direction rapidly and accurately (Barrow & McGee, 1971; Johnson & Nelson, 1969). In more recent publications, some authors have defined agility to include whole-body change of direction as well as rapid movement and direction change of limbs (Baechle, 1994; Draper & Lancaster, 1985).