# Enhancing Performance & Preventing Injuries in Team Sport Players

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# Repeated Modified Agility T-test: Role of the energy systems and anthropometrics in team sport players

Journal of Sport and Health Science - submitted

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*The aim of this study was to determine 1) the relation between the anaerobic and aerobic energy systems and RMAT performance and 2) to what extent this relation is affected by anthropometrics in male and female indoor team sport players. Twenty-three male and 31 female players performed a repeated Wingate Anaerobic Test (WAnT), a $VO_2max$ test and a RMAT. The RMAT consists of 10 sprints with changes of direction, starting every 30 seconds. Prior to testing general anthropometrics were measured. Pearson correlations showed for the WAnT higher absolute power (Watt) resulted in faster Total Time (sec) of the RMAT in female players (r= -0.36 - -0.45, p ≤0.05). Taller and heavier female players had a faster Total Time (sec) of the RMAT (r= -0.50 and -0.37 respectively, p ≤0.05). For male players no relations with RMAT performance were found. The multiple regression model for Total Time of the RMAT in female players showed an explained variance of 22% for height. The remaining variables did not significantly contribute to the model. In conclusion, in female players a better anaerobic energy system is related to faster RMAT performance. However anthropometrics, especially height, seem to be slightly more dominant than the contribution of the energy systems.*

Keywords: physiology, testing, agility, height

## INTRODUCTION

Physical game demands of indoor team sports, such as basketball and volleyball, involve repeated short bouts of high-intensity or maximal exercise alternated with periods of low-intensity activities, also described as repeated sprinting [12]. These high-intensity activities include quick changes in forward, backward and lateral directions while accelerating and decelerating usually in reaction to a stimulus such as an opponent or ball [2,25,26]. These activities fit the definition of agility; "a rapid whole-body movement with change of velocity or direction in response to a stimulus" [26]. The physical component of agility is known as change of direction speed (CODS) [26,29].

High-intensity activities place high demands on the anaerobic energy system [21] and over the game the contribution of the aerobic energy system slowly increases [12,13,27]. So, the anaerobic and aerobic energy systems seem important as performance indicators for CODS. The Repeated Modified Agility T-test (RMAT) is proposed to measure CODS for indoor team sports [14,24]. However, it is not clear to what extend the energy systems are related to RMAT performance.

Only one study investigated the role of the anaerobic energy system in RMAT performance. A higher absolute and relative peak and mean power output on a 30 second Wingate test resulted in faster peak and total sprint times on the RMAT in male college students [14]. These findings are in line with the results of studies investigating the role of the anaerobic energy system in repeated straightforward sprinting in both male [2,18] and female players [17].

The contribution of the aerobic energy system to RMAT performance is not yet known. However, from straight sprint tests it appears that this contribution depends on characteristics of the field test protocol (trajectory, duration and number of repetitions) [7]. It has been shown that a higher absolute and relative $VO_2$max was related to faster sprint times when the protocol consisted of longer sprints [1,16,17]. This was the case for peak time and total sprint time in repeated straight sprint tests. On the contrary no relation was found between absolute and relative $VO_2$max and sprint times on repeated sprint tests in male players with protocols involving sprints of shorter duration [3,10,18]. In sum, protocols with sprints of longer duration and more repetitions depend heavier on the aerobic energy system compared to protocols involving sprints of shorter duration and fewer repetitions.

Anthropometrics, in terms of both body weight and height, are suggested to influence CODS [26]. Heavy players may find it difficult to coordinate the directional changes while accelerating and decelerating [8]. Height has only been investigated in relation to lunge performance, which accounted for 85% of the common variance [9]. Most research up until now confirms that male and female players with more body mass have a slower CODS [8,19]. Since more body mass is also related to lower relative $VO_2max$ and lower vertical jump height as an indicator of anaerobic power [20], both body weight and height might affect the relation between energy systems and CODS.

Up until now studies investigating CODS did not look specifically at the role of both anaerobic and aerobic energy systems and anthropometrics at the same time. Studies that did include the role of both energy systems are limited to straightforward sprinting. Furthermore, the role of the energy systems has not been studied in both male and female players within the same study using the same protocol. Agility studies with female players are limited but some differences appear to exist between sexes [1,17,18]. Therefore, the aim of this study was to determine the relation between the anaerobic and aerobic energy systems and RMAT performance along with discovering to what extent this is affected by anthropometrics in male and female indoor team sport players.

## METHODS

### Subjects

Fifty-four sub-elite volleyball, basketball, floorball and korfball players; 23 males (mean±SD: age 21.9 ± 2.7 yr, body mass 85.2 ± 10.8 kg, height 191.9 ± 5.1 cm) and 31 females (mean ± SD: age 21.9 ± 3.2 yr, body mass 69.7 ± 9.9 kg, height 176.1 ± 6.8 cm) participated in this study. Sub-elite was defined as playing at the highest regional or national level having on average three weekly training sessions and one game a week. After being fully informed about the study, each player signed an informed consent. The study was performed in accordance with the guidelines of the medical ethical committee of the University Medical Center. This study is part of a larger study called Groningen MAPS; Groningen Monitoring Athletic Performance Study.

### Procedures

A cross-sectional study design was used. At the start of the 2011-2012 season anaerobic and aerobic capacities (independent variables) were measured in the exercise lab with the repeated WAnT and a $VO_2max$ test, respectively. Also general anthropometrics were measured. To measure CODS (dependent variable) the RMAT was performed indoor within 6 weeks. For both laboratory tests players were asked to restrain from eating and drinking anything except water two hours prior to testing. During all tests players were verbally encouraged by the test instructor to evoke maximal effort. To exclude cardiovascular risks a sports medical physician screened all players according to the Lausanne recommendations [5].

*Anthropometrics.*

Prior to the tests in the lab, general anthropometrics were measured in terms of body mass and height. Body mass in kg was measured with a Tanita BC-418MA (Tanita corp, Tokio, Japan), which showed good validity and reliability [15]. Height in cm was measured by using a tape measure attached to a wall with a sliding horizontal headpiece which was placed on the top of the head in a 90°angle. Players were asked to remove their shoes and stand erect with the heels together [22].



*Repeated Wingate Anaerobic Test.*

The 30-second WAnT is the most common test to measure anaerobic power. However, this protocol does not reflect the characteristics of the high-intensity activities in indoor team sports. Therefore a repeated WAnT protocol was developed to reflect the game demands of indoor team sports with an intermittent character [17,27]. The repeated WAnT was performed on a cycle ergometer (Excalibur Sport, Lode B.V., Groningen, The Netherlands). The test started with a warm up period of five minutes at a resistance of 150 Watts for males and 100 Watts for females. Players were asked to keep the pedal frequency on a self-chosen RPM between 80 and 90 during the warm up and active rest periods. The protocol consisted of 6 all out sprints of 10 seconds from a rolling start with one minute of active rest in between. The resistance for the sprints was set at a torque factor of 0.75 times body mass [4]. Performance was expressed as Peak Power Output (PPO), Total Peak Power Output (TPPO), Mean Power Output (MPO) and Total Mean Power Output (TMPO). The PPO and MPO refer to the highest power output and TPPO and TMPO to the total power output from the six sprints together.

*$VO_2$max test.*

A $VO_2$max test was executed to determine the maximal aerobic capacity and was assessed on a treadmill (Valiant, Lode B.V., Groningen, The Netherlands) using a ramp protocol. After a five minute warm up period at eight $km \cdot h^{-1}$ with a slope of two percent, the velocity gradually increased with 0.8 $km \cdot h^{-1}$ each minute until 18 $km \cdot h^{-1}$. After 18 $km \cdot h^{-1}$ the slope increased by one percent each minute. Players ran until volitional exhaustion. Metabolic measurements were made using a breath-by-breath gas analyzer (Cortex Metalyzer 3B, Procare B.V. Groningen, The Netherlands). The highest $VO_2$ was determined as a moving average over 30 sec when at least two of the following criteria were met: (1) respiratory exchange ratio value of at least 1.15, (2) the Rating of Perceived Exertion after the test was above 18, and (3) the $VO_2$ reached a plateau [6,11]. Both RER and RPE were measured and the $VO_2$ plateau was determined based on visual inspection of the data.

For both the repeated WAnT as well as the $VO_2$max test performance was expressed in absolute and relative measures to investigate the affect of anthropometrics on the relationship between the energy systems and CODS.

*Repeated Modified Agility T-test.*

CODS was measured by way of the RMAT [24]. The RMAT was performed using the protocol described by Haj-Sassi et al. (2011) consisting of ten maximal sprints starting every 30 seconds. The players started at the start line placed 55cm before A. After a countdown from 3, the athletes sprinted forward towards mark B, shuffled left or right to C or D, shuffled back to B onward to C or D, back to B and ran backwards to A (Figure 1). Players were instructed not to cross their feet while shuffling, and touch the tape at B,C and D with their feet. In contrast to the protocol of Haj-Sassi et al. (2011), where they touched the mark with their hand, the mark was touched with their feet being more sport specific. Sprint times were recorded using an electronic timing system (TAG Heuer, Marinn, Swiss), which was positioned at either side of mark A. The sensors were mounted on tripods and placed 1.35 m above the ground (approximately at shoulder height). The performance indices were the fastest time of the ten sprints named Peak Time (PT) and Total Time (TT) of the ten sprints. Both indices have shown to be reliable illustrated by an ICC (95% CI) of 0.94 (0.77-0.99) and 0.97 (0.89 – 0.99) for PT and TT respectively. Furthermore, validity was supported against vertical and horizontal jumping ($r$ = -0.43 to -0.72; $p \leq 0.05$) [14].

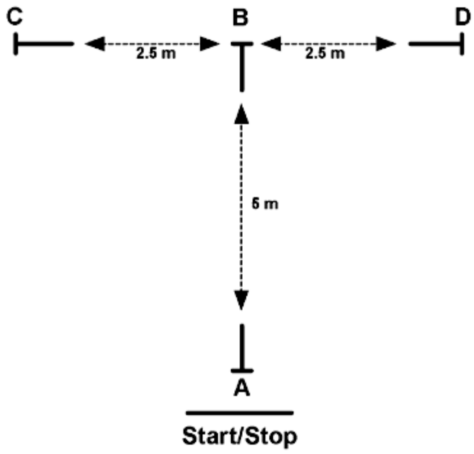


Figure 1. Repeated Modified Agility T-test (RMAT) modified from Haj-Sassi et al. [14]



**Statistical analysis**

Data analysis was performed using IBM SPSS Statistics 20 for Windows. Descriptive statistics (means and standard deviations) were computed for all variables. Pearson product-moment correlations were calculated to determine the relationship between the various performance indices including anthropometrics. First the relationship of the performance indices of the multiple WAnT and the $VO_2max$ with the performance of the RMAT was determined. Second, the relationship of the anthropometrics with performance of the RMAT was determined. With backward stepwise multiple regression analysis the contribution of the multiple WAnT, the $VO_2max$ performance indicators and anthropometrics to the variance of the RMAT scores was determined. The indicators with the best single correlation were added to the model of the RMAT scores. These correlations and regression models were computed for male and female players separately. The level of statistical significance was set at $p \leq 0.05$.

| | Male | | | Female | | |
|---|---|---|---|---|---|---|
| *Multiple WAnT* | | | | | | |
| PPO (W) | 1611.75 | ± | 244.08 | 1103.91 | ± | 191.56 |
| TPPO (W) | 8487.55 | ± | 1308.28 | 5999.74 | ± | 1008.72 |
| PPO ($W \cdot kg^{-1}$) | 18.92 | ± | 1.83 | 15.84 | ± | 1.44 |
| TPPO ($W \cdot kg^{-1}$) | 99.70 | ± | 10.17 | 86.07 | ± | 7.00 |
| MPO (W) | 1049.91 | ± | 118.56 | 714.69 | ± | 105.28 |
| TMPO (W) | 5266.57 | ± | 561.90 | 3798.64 | ± | 548.78 |
| MPO ($W \cdot kg^{-1}$) | 12.37 | ± | 0.97 | 10.28 | ± | 0.77 |
| TMPO ($W \cdot kg^{-1}$) | 62.24 | ± | 6.22 | 54.66 | ± | 4.38 |
| *$VO_2max$ test* | | | | | | |
| $VO_2max$ ($l \cdot min^{-1}$) | 4.25 | ± | 0.34 | 2.97 | ± | 0.32 |
| $VO_2max$ ($ml \cdot min^{-1} \cdot kg^{-1}$) | 50.36 | ± | 5.28 | 42.95 | ± | 4.67 |
| *RMAT* | | | | | | |
| Peak Time (s) | 5.48 | ± | 0.24 | 6.20 | ± | 0.41 |
| Total Time (s) | 57.48 | ± | 2.35 | 64.82 | ± | 4.00 |

Table 1. Descriptive data of the Multiple Anaerobic Wingate test (WAnT), $VO_2max$ test and Repeated Modified Agility T-test (RMAT) for male ($n$ =23) and female ($n$ =31) players. Values are mean±*SD*. PPO= Peak Power Output; TPPO = Total Peak Power Output; MPO = Mean Power Output; TMPO = Total Mean Power Output

**RESULTS**

The descriptives for the multiple WAnT, the $VO_2max$ test and the RMAT are presented in Table 1 for both male and female players.

For male players there was no relation between performance indices of the multiple WAnT the $VO_2max$ test, and RMAT performance. Next, the results showed that female players with higher absolute PPO, TPPO and MPO of the multiple WAnT had faster TT of the RMAT (r= -0.45, -0.41 and -0.36 respectively; $p \leq 0.05$).

The relationship between anthropometrics and performance of the RMAT, specifically TT, are shown in Figure 2 and 3. Anthropometrics and RMAT performance were not related in male players. However, taller female players had faster PT (r =-0.40; $p \leq 0.05$) and TT (r =-0.50; $p \leq 0.01$, Figure 2) of the RMAT and heavier female players had faster TT (r =-0.37; $p \leq 0.05$, Figure 3).

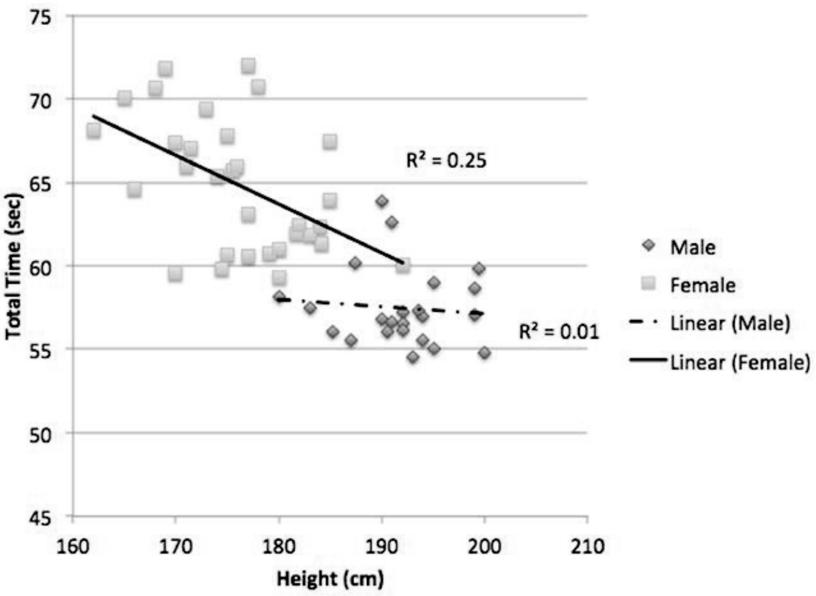


Figure 1. Relationship between height (cm) of male and female players separately and total time of the Repeated Modified Agility Test (RMAT).

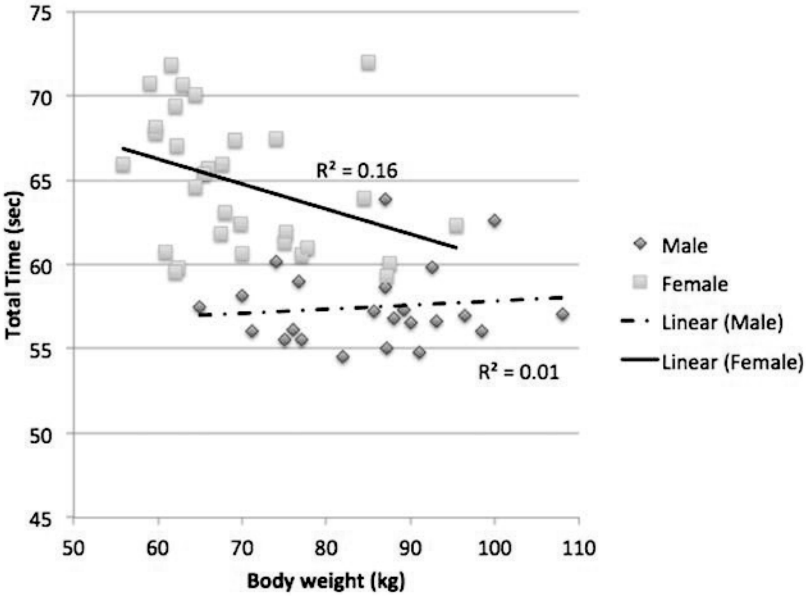


Figure 2. Relationship between body weight (kg) of male and female players separately and total time of the Repeated Modified Agility Test (RMAT).

The results of the backward multiple regression analysis showed no significant models for male players, neither for PT in female players. Table 2 shows the results for the regression model made for female players of the TT of the RMAT. The model for TT on the RMAT showed a 22% explained variance of height in female players. The PPO did not contribute significantly to the model.

| | Step | Constant | Beta | $R^2$ | *p* |
|---|---|---|---|---|---|
| **Total Time** | 1 | 107.32 | | 0.23 | |
| | PPO | | -0.237 | | 0.240 |
| | Height | | -0.357 | | 0.082 |
| | 2 | 116.28 | | 0.22 | |
| | Height | | -0.496 | | 0.005 |

Table 2. Backward stepwise multiple regression for the Total Time (TT) on the Repeated Modified Agility Test (RMAT) of the female ($n$ =31) team sport players. PPO= Peak Power Output; Beta = standardized beta weights; $R^2$= Shared variance

## DISCUSSION

This study aimed to determine the relation between the anaerobic and aerobic energy systems and RMAT performance in male and female indoor team sport players. The second aim was to discover to what extent this is affected by anthropometrics. Female players with higher absolute anaerobic power and females that were taller and heavier showed faster TT of the RMAT. Height showed to be the best predictor for TT of the RMAT in females. No significant relation was found between $VO_2$max and RMAT performance. For male players there was no significant relation between anaerobic and aerobic energy systems, anthropometrics and RMAT performance. It should be noted that relations were found with TT of the RMAT but not with PT. This may be due to the repeated protocol, enabling a pacing strategy. This is supported by the large inter-individual differences between the sprints in which players reached their PT; some in their first sprint and others during the last. As a result maximal PT may not be reached.

Although in female players the anaerobic system indeed contributed to RMAT performance, this was not the case for male players. The latter is in contrast with previous findings showing higher relative and absolute anaerobic power resulting in both faster PT and TT [14]. An explanation for this can be that the male players in the study of Haj-Sassi et al. (2011) had comparable anthropometrics as our female players. In contrast, our male players are much taller and heavier. Being taller the players may have an advantage being able to take bigger steps and touch the marks more easily with their feet during the RMAT protocol. The optimal height of around 1.90m (Figure 2) probably coincides with an optimal step length that is beneficial for the task. However, when players are taller than this optimum it seems that their weight becomes a disadvantage. Being heavier the male players may have more difficulty with the quick accelerations and decelerations needed for CODS tests [8,20,28]. The fact that the male group was more homogenous regarding length and weight may have weakened this relation even more.

Another explanation for the fact that weaker and more non-significant relations were found between the anaerobic energy system and RMAT performance may be in the protocols used for anaerobic power and CODS. The movements in the RMAT protocol may require coordination and motor skills, while the multiple WAnT just involves a simple cyclic movement. In addition, in the RMAT protocol of Haj-Sassi et al. (2011) the players touched the mark with their hand in contrast to our protocol where the mark was touched with their feet increasing the advantage for players with wider step length.

Between $VO_2max$ and RMAT performance no relation was found in both male and female players. Studies up until now show no consistent results [8,10,16,17]. This may be due to the differences in protocols varying in the duration of sprints and of recovery between sprints. The protocols used in the studies showing a relation between $VO_2max$ and CODS [8] or repeated sprinting [1,16,17] have sprints of longer duration with relatively short recovery periods, around eight and ten seconds respectively. On the contrary the protocols of studies showing no relation involve sprints of shorter duration with relatively longer recovery periods [3,10,18]. In the latter studies players are able to recover sufficiently to be able to use mainly the anaerobic energy system for the successive sprints. Our protocol is in line with these studies since it consisted of five-second sprints, with 25 seconds of recovery in between. This is probably enough to recover in between sprints. The TT of our players of the RMAT supports this since there seem to be no decrease over the 10 sprints indicating sufficient recovery. As stated before it seems that the duration of sprints and recovery between sprints determine the role of the aerobic energy system [7]

A recent study shows that jumping, sprinting and CODS are independent motor abilities, having a low common variance ranging from six to 23% [23]. In our study the results indicated a more important influence of anthropometrics compared to the aerobic or anaerobic energy system. Anthropometrics explained 25% ($r = -0.50$; $R^2 = 0.25$) of the variance in female players, while for the anaerobic energy system this was 20% ($r = -0.45$; $R^2 = 0.20$). This indicates that CODS is an independent motor ability. It can be argued that compared to the WAnT, jump and straight sprint tests this motor ability is especially relevant for CODS. This means that in male and female players it is important to use separate performance tests to asses the aerobic and anaerobic energy system as well as CODS, jump and straight sprint performance.

This study is the first to include to what extent the relation between the anaerobic and aerobic energy systems and RMAT performance is affected by anthropometrics. Furthermore in this study both male and female players participated and the results were presented separately. To conclude, in female players a better anaerobic energy system was weakly related to better RMAT performance. Height showed to be the best single predictor for RMAT performance. The aerobic energy system does not seem to play a role in CODS. The energy systems don't seem to be dominant in CODS, anthropometrics seem to play a more important role in CODS.

## PRACTICAL APPLICATIONS

CODS plays an important role in indoor team sports. Although the anaerobic energy system influence RMAT performance in female players anthropometrics seem to be slightly more dominant. This may be taken into account when testing CODS and interpreting the performance on CODS tasks. The role of the energy systems in CODS is limited therefore other tests should be used to specifically test the anaerobic and/or aerobic energy systems.

## ACKNOWLEDGEMENTS

The authors would like to thank all players and coaches of the Groningen Monitoring Athletic Performance Study (MAPS) who took part in this study. We also like to thank the staff and students participating in the SportsFieldLab Groningen in the study year 2011-2012 and 2012 – 2013 for their assistance in the data collection. This work was supported by the SIA RAAK-PRO under Grant PRO-2-018.

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