Title:

Bigger, stronger, faster, fitter: the differences in physical qualities of school and academy rugby union players

Authors:

*Ben Jones[1,2,3,4], Dan Weaving[1,4], Jason Tee[1], Joshua Darrall-Jones[1,5], Jonathon Weakley[1,2], Padraic Phibbs[1,2], Dale Read[1,2], Gregory Roe[1,6], Sharief Hendricks[1,7] and Kevin Till[1,2,4]

Affiliations:

[1]Institute for Sport, Physical Activity and Leisure, Leeds Beckett University, Leeds, UK
[2]Yorkshire Carnegie Rugby Union club, Leeds, UK
[3]The Rugby Football League, Leeds, UK
[4]Leeds Rhinos Rugby League club, Leeds, UK
[5]Wasps Rugby Union club, Coventry, UK
[6]Bath Rugby Union club, Bath, UK
[7]University of Cape Town, Division of Exercise Science and Sports Medicine, Cape Town, South Africa

Abstract

Limited research has compared the physical qualities of adolescent rugby union (RU) players across differing playing standards. This study therefore compared the physical qualities of academy and school Under-18 RU players. One-hundred and eighty-four (professional regional academy, n = 55 school, n = 129) male RU players underwent a physical testing battery to quantify height, body mass, strength (bench press and pull-up), speed (10, 20 and 40 m), 10 m momentum (calculated; 10 m velocity * body mass) and a proxy measure of aerobic fitness (Yo-Yo Intermittent Recovery Test Level 1; IRTL1). The practical significance of differences between playing levels were assessed using magnitude- based inferences. Academy players were taller (very likely small), heavier (likely moderate) and stronger (bench press possibly large; pull-up plus body mass likely small) than school players. Academy players were faster than school players over 20 and 40 m (possibly and likely small), although differences in 10 m speed were not apparent (possibly trivial). Academy players displayed greater 10 m momentum (likely moderate) and greater IRTL1 performance (likely small) than school players. These findings suggest that body size, strength, running momentum, 40 m speed and aerobic fitness contribute to a higher playing standard in adolescent rugby union.

Introduction

Rugby union (RU) is played at youth and senior levels across numerous pathways in England. RU participation in England is higher than any other country (Freitag, Kirkwood, & Pollock, 2015). Due to the physically demanding nature of the game, well-developed physical qualities (e.g., body size, strength, speed and aerobic fitness) are important attributes for rugby union players (Darrall-Jones, Jones, & Till, 2015). However, to date there is limited understanding of how the physical qualities differ between playing standards, which has implications for talent identification and long-term player development.

The identification and development of talented youth players is an increasing focus for professional clubs and national governing bodies across a number of sports (Reilly, Williams, Nevill, & Franks, 2000; Till et al., 2015). A key area of identification is to establish the differences in physical qualities between playing standards and age categories due to their emerging associations with long-term player performance (Boccia et al., 2017; Till et al., 2015; Till, Scantlebury, & Jones, 2017). For example, in youth rugby league players (< 18 yrs.), greater physical qualities (10-m sprint performance; $r = 0.60$) were associated with greater 1 vs. 1 tackling ability and more successful ball carries (10- m sprint momentum; $r = 0.61$ to 0.69) during matches (Gabbett, Jenkins, & Abernethy, 2010). In addition, players who possessed greater physical qualities were more likely to start competitive matches (Gabbett, Kelly, Ralph, & Driscoll, 2009) and demonstrate lower post-match fatigue characteristics (Johnston, Gabbett, Jenkins, & Hulin, 2014) in spite of greater match demands (Johnston, Gabbett, & Jenkins, 2015; Johnston et al., 2014). Collectively, the afore- mentioned findings partially contribute to adolescent players attaining professional playing status (Till et al., 2015). Given the similarities between rugby league and RU, this research suggests that the physical qualities of adolescent RU players across all playing pathways should be a key consideration for coaches to optimise player performance.

Recently, Darrall-Jones, Jones, et al. (2015) examined the physical qualities of academy RU players by age (e.g., U16, U18 and U21). Findings identified differences in height and body mass, countermovement jump height and power, and relative and isometric strength were discriminated between age categories (Darrall-Jones, Jones, et al., 2015). However, no differences were identified for 10, 20 and 40 m sprint times and high-intensity running ability (Yo-Yo Intermittent Recovery Test Level 1 [IRTL1] and 30–15 intermittent fitness test), although these similar results were achieved in the presence of increased body mass (Darrall-Jones, Roe, et al., 2015). This seems to indicate that the ability to increase strength, power and body mass
while maintaining running ability is important for the development of RU players within the academy pathway.

There are currently limited studies comparing the physical qualities of adolescent RU players across different playing levels to suggest how physical qualities may contribute to advanced player selection (Phibbs et al., 2017a; Read et al., 2017). A comparison between school and academy levels in England may be of interest as these playing competitions are distinct from each other, but players regularly interchange between the two pathways (Phibbs et al., 2017b). In addition, while academy rugby is considered to be of a higher standard than schools rugby, and there are some differences in the movement demands at these different levels of the game (Read et al., 2017), both competitions form part of the overall England player development pathway (Phibbs et al., 2017a). The aim of the academy pathway is to progress players towards the elite levels of the game. At present, there is limited information regarding whether school players possess the appropriate physical qualities to participate in competition within the school pathway and if selected, to advance to additional levels of the performance pathway (e.g. representative or academy). Therefore, the aim of this study was to compare the physical qualities between academy and school Under 18 rugby union players.

Methods

Participants

A total of 55 U18 male RU players (n = 28 forwards and n = 27 backs; age: 17.5 ± 0.6 yrs.) from a professional regional academy and 129 U18 male RU players (n = 64 forwards and n = 65 backs; age: 17.3 ± 0.6 yrs.) from 4 local independent schools participated in the study. Playing positions were classified by a player's primary playing position, although players did report playing various positions. If an academy player attended one of the independent schools, they were not included within the school data. All experimental procedures were approved by a University's ethics committee with informed and parental con- sent obtained when a player was under 18 years at the time of data collection.

Procedures

For all players, testing was conducted across two sessions in the pre-season period. Participants were instructed to rest in the 48 hours prior to the testing sessions. The first session comprised of anthropometric (height and body mass), sprint (10, 20 and 40 m) and Yo-Yo IRTL1 tests outdoor on an artificial pitch. The second session comprised of three repetition maximum (3 RM) strength (bench-press, pull-ups) tests which were conducted in a gym. All tests were performed in the order described. Lower body testing was excluded from the design given the limited resistance training experience and lack of technical competency of some players. Prior to all testing sessions a standardised warm-up was administered.

Anthropometry

Body mass and height were measured to the nearest 0.1 kg and 0.1 cm respectively using calibrated (SECA model 220, Birmingham, United Kingdom) scales and stadiometer (SECA Alpha, Birmingham, United Kingdom).

Sprint time and momentum

Sprints were measured at 10, 20 and 40 m using timing gates (Brower Timing Systems, IR, Emit, USA). Players completed three maximal sprints with 3-minutes passive recovery between bouts. Participants started each sprint 0.5 m behind the starting timing gate with the best of three attempts at each split (10, 20 or 40 m) measured to the nearest 0.01 s retained for analysis. Velocity was calculated for the 10 m distance, and then multiplied by body mass to calculate 10 m momentum. The intraclass correlation coefficient (ICC) and coefficient of variation (CV) for 10, 20 and 40 m sprint times have previously been reported to be r = 0.94 and CV = 1.4%, r = 0.90 and CV = 1.7% and r = 0.96 and CV = 1.2% respectively within academy adolescent RU players (Darrall-Jones, Jones, et al., 2015).

Yo-Yo IRTL1

The Yo-Yo IRTL1 was used as a proxy measure of aerobic capacity. While the test is not a true measure of aerobic performance per se, given the duration of the test, the aerobic system will make the largest proportionate contribution to energy production (Krustrup et al., 2003). The Yo-Yo IRTL1 was completed as frequently described in previous methods (Krustrup et al., 2003) with the total distance covered at the point of termination of the test used for analysis. The ICC and CV for the Yo-Yo IRTL1 has previously been reported as r = 0.98 and CV = 4.6% respectively (Krustrup et al., 2003).

Strength

Participants completed 3 RM bench-press and neutral grip pull-ups to determine upper body pushing and pulling strength. For the bench press, players chose a self-selected grip on the barbell. The barbell was required to touch the chest and return to a completed locked out position without assistance for the 3 RM to be recorded. During the neutral grip pull-ups, players completed the lift from a dead hang with elbows locked out and head in front of the arms. To complete the repetition, they were instructed to pull themselves to a position in which the chest came into contact with the bar. External weight was attached to the player via a chinning belt. Pull-ups, plus the participant's body mass was also included in the analyses.

Statistical analyses

Magnitude based-inferences were used to assess the practical significance of the differences between school and academy under-18 rugby union players in all dependent variables (Hopkins, Marshall, Batterham, & Hanin, 2009). Data were analysed using a specially formatted spreadsheet (Hopkins, 2017). Each dependent variable was log transformed to allow for effects and variations to be presented as percentages (Taylor, Hopkins, Chapman, & Cronin, 2016). Means and standard deviations of dependent variables were back transformed prior to reporting. Initially, the probability of a difference being greater than a small effect (effect size [ES] > 0.2) was calculated and rated as <0.5%, almost certainly not; 0.5–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99.5%, very likely; >99.5%, almost certainly (Hopkins et al., 2009). In the event that the magnitude of difference was almost certainly small, and demonstrated a mean difference greater than a moderate standardised effect (ES > 0.6), the probability of change being greater than a moderate effect was assessed. In the event that the magnitude of difference was also almost certainly moderate, and demonstrated a mean difference of greater than a large standardised effect (ES > 1.2), the probability of change being greater than a large effect was assessed. Where the probabilities of a substantial positive and negative change were both greater than 5%, the effect is considered unclear (Batterham & Hopkins, 2006; Hopkins et al., 2009). In the event a finding was clear but the probability of the effect being greater or less than the considered effect was <25%, the effect was rated as trivial. Finally, where a finding was clear but demonstrated possible chances of being both trivial and substantial, the change was only considered possibly substantial when the probability of a substantial finding was greater than that of trivial.

Results

The mean ± standard deviation of the physical qualities for school and academy players, mean differences and standardised mean differences between the two standards for each physical quality are shown in Table 1.

Differences in anthropometric characteristics were apparent between levels with academy players taller (very likely small) and heavier (likely moderate) than school players. Academy players had a stronger bench press (possibly large), and pull-up when including body mass (likely small), although the external load added to the pull up was less for Academy players (possibly moderate). Academy players had a likely moderate greater 10 m momentum than School players.

Differences in running ability were less pronounced. Sprint times over 10, 20 and 40 m displayed possibly trivial, possibly small and likely small differences with academy players faster for 20 and 40 m. There was a likely small difference in IRTL1 performance favouring the academy players.

Discussion

This is the first study to compare the physical qualities between U18 school and academy level RU players. The findings demonstrated that there were meaningful differences in the physical qualities between levels. Academy players were physically superior to school players in height, body mass, strength (bench-press and pull-up including body mass), 20 and 40 m sprint, 10 m sprint momentum and Yo-Yo IRTL1 performance, but not 10 m speed or load added to pull up. These findings are expected, as it has repeatedly been demonstrated that physical characteristics differ across levels in rugby (Duthie, Pyne, & Hooper, 2003; Gabbett, King, & Jenkins, 2008). Such research provides important information for coaches looking to progress players through levels of the game by highlighting the important physical characteristics that need to be developed.

Among the key findings of this study were a very likely small difference in height and a likely moderate difference in body mass between academy and school players. Due to RU's collision demands, emphasis is naturally placed on the ability to physically dominate opponents within contact, resulting in either a potential selection bias towards physically bigger players (Duthie et al., 2003; Jones et al., 2015), or that players within the academy are exposed to superior physical development programmes, thus have increased body mass. The emphasis on developing superior physical size within the game has been demonstrated by a 20% increase in the mean body mass of an elite representative team over the past decade (Lombard, Durandt, Masimla, Green, & Lambert, 2015). Similar trends are present in English professional rugby union (Fuller, Taylor, Brooks, & Kemp, 2013). Clearly the sport favours physically large players, and academy selection or the physical development focus appears to reflect this.

The physical demands of RU necessitate well-developed strength and repeated effort abilities (Duthie, 2006; Duthie et al., 2003; Gamble, 2004). The application of strength and conditioning practices within RU has led to large improvements in these physical qualities throughout the sport (Austin, Gabbett, & Jenkins, 2011; Duthie, 2006; Lombard et al., 2015; Weakley et al., 2017). For example, Lombard et al. (2015) has demonstrated 50% improvements in muscular strength (bench-press) and muscular endurance (pull-ups) over the past 13 years in an international U20 team. The necessity for improved physical conditioning at higher levels of the game is reflected in the differences in upper body pulling and pushing strength between the academy and school level players. Similarly, to the differences observed for body mass between the two groups, it is unclear if this finding is indicative of stronger players being recruited, or if indeed specialist strength and conditioning support is provided to academy players, facilitating greater strength development. Given players can be recruited into an academy between the ages of 14 and 18 years old, it is likely both factors contribute to the observed differences. This is further supported by observations that school level athletes participate in strength and conditioning practices (Weakley et al., 2017), thus will also experience developments in strength, alongside other physical qualities.

An unexpected finding was the relatively small differences in sprint performance between school and academy players, with no differences apparent for 10 m. This is despite academy players being exposed to more sprint activity during training than school players (Phibbs et al., 2017a). Speed is regularly listed as an important physical characteristic for RU performance (Duthie, 2006; Duthie et al., 2003; Gamble, 2004). Despite this, speed has not been demonstrated to be a discriminator of talent across levels of the game (Duthie et al., 2003). This may be due to the fact that there is large variation in speed qualities between players in different positions within the game (e.g. prop vs. winger) (Duthie et al., 2003), and thus far these differences have not been taken into account when comparing speed across levels of the game. Recent research has demonstrated that sprint speed does not differentiate across age groups within RU talent pathways (Darrall-Jones, Jones, et al., 2015; Howard, Cumming, Atkinson, & Malina, 2016). However, the combination of sprinting velocity and body mass, sprint momentum, has previously been able to discriminate between playing levels (Baker & Newton, 2008; Barr, Sheppard, Gabbett, & Newton, 2014) and age categories (Till et al., 2014) across both rugby codes.

In the current study, academy players possessed greater body mass than school players, and the magnitude of this difference was likely moderate. In the context of similar 10 m sprint times between groups, this meant that academy players were capable of generating likely moderately greater sprint momentum. This finding appears to emphasise the importance placed on physical size within the game that is likely reflected in selection policies and/or physical development programs. It should be noted that despite the lack of differentiation in absolute speed across increasing age groups, the maintenance of absolute speed in the context of significantly increased body mass is indicative of improved strength-power qualities. Therefore, increasing body mass and strength-power qualities remain principal outcomes for rugby physical development programs.

While it is clear that physical size and strength are important physical qualities for RU players, what is unclear is what the ideal talent development approach is to develop these qualities within development pathways. Relative age effects (RAE) have been identified throughout age-group levels of RU selection (Grobler, Shaw, & Coopoo, 2016; Lewis, Morgan, & Cooper, 2015; McCarthy, Collins, & Court, 2016), demonstrating the bias towards selecting physically bigger players, which was not accounted for within this study for a number of reasons, discussed in the limitations of this study. That said, the age of the two groups were similar, thus it is unlikely the differences observed were simply due to age. RU selection processes have also been shown to be biased toward early- and on-time maturers, with no late maturers identified within a sample of 14–17 year old academy rugby players (Howard et al., 2016), which was also not accounted for in this study. Collectively, these findings suggest that academies are likely to select taller, heavier players in the junior age groups, how- ever this may not represent an optimal selection strategy for long term success.

Research in RU and rugby league has previously demonstrated that early (de)selection policies are likely flawed due to the ability for late-maturers to catch up with and potentially overtake the physical characteristics of early maturing players (Cobley, Till, O'Hara, Cooke, & Chapman, 2014; McCarthy et al., 2016; Till, Cobley, O' Hara, Cooke, & Chapman, 2014). It is difficult to determine from these data what proportion of the physical characteristic differences between academy and school players is attributable to genetic predisposition, and what part of the advantage is related to early selection and training. Players selected early by academy structures will benefit from the provision of professional strength and conditioning services and nutrition support. If school players were provided with similar training exposure, they may continue to develop at a similar rate, which may benefit the wider game of RU. This is therefore a recommendation for schools to provide appropriate physical development opportunities for players, which appear to be inconsistent at present (Weakley et al., 2017).

There were a number of limitations to this research study that will need to be overcome by future investigations in this area. It was not possible to assess lower body strength due to a lack of lifting competency within a number of the players in the school pathway. This further highlights the mismatch in training provision across the pathways. Future research may look to include lower body strength measures such as squat, leg press or isometric mid-thigh pull to determine whether there are important differences in this area. A further limitation of this study is the lack of differentiation of players into their positions or position groups. This was not possible in the current study because differentiation into position groups would have made the sample size too small to make meaningful comparisons. Furthermore, a number of players within both pathways regularly changed between positions or positional groups making it difficult to compare. In addition, this research only examined a single age-group (U18) within the player pathway. In order to gain a more meaningful under- standing of the developmental journey of players within these pathways it will be necessary to examine age groups across the pathway spectrum. Future research incorporating a much larger sample may manage to overcome these challenges. Finally, as this study did not account the duration of time that academy players had been in the academy, or adopt a longitudinal design across age-groups, it was not possible to identify what proportion of the differences were due to selection practices or indeed training adaptations.

In conclusion, this study is the first to compare the physical qualities of RU players within the school and academy player development pathways within England. It was determined that there are meaningful differences in the physical qualities of players competing at different standards of competition. Academy level players were demonstrated to possess superior height, body mass, strength, 20 and 40 m sprint, 10 m momentum, aerobic fitness than school level players. Such findings emphasise the importance of physical qualities for playing level in adolescent RU and suggests strategies should be in place to maximise the development of such qualities in school and academy RU programmes.

References

Austin, D., Gabbett, T., & Jenkins, D. (2011). The physical demands of super 14 rugby union. Journal of Science and Medicine in Sport, 14, 259–263.

Baker, D. G., & Newton, R. U. (2008). Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. Journal of Strength and Conditioning Research, 22, 153–158.

Barr, M. J., Sheppard, J. M., Gabbett, T. J., & Newton, R. U. (2014). Long- term training-induced changes in sprinting speed and sprint momentum in elite rugby union players. Journal of Strength and Conditioning Research, 28, 2724–2731.

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. International Journal of Sports Physiology and Performance, 1, 50–57.

Boccia, G., Moisè, P., Franceschi, A., Trova, F., Panero, D., La Torre, A., . . . Cardinale, M. (2017). Career performance trajectories in track and field jumping events from youth to senior success: The importance of learning and development. PLoS One, 12, e0170744.

Cobley, S. P., Till, K., O'Hara, J., Cooke, C., & Chapman, C. (2014). Variable and changing trajectories in youth athlete development: Further verification in advocating a long-term inclusive tracking approach. Journal of Strength and Conditioning Research, 28, 1959–1970.

Darrall-Jones, J. D., Jones, B., & Till, K. (2015). Anthropometric and physical profiles of English academy rugby union players. Journal of Strength and Conditioning Research, 29, 2086–2096.

Darrall-Jones, J. D., Roe, G. A. B., Carney, S., Clayton, R., Phibbs, P., & Jones, B. (2015). The effect of body mass on the 30–15 intermittent fitness test in rugby union players. International Journal of Sports Physiology and Performance, 11, 400–403.

Duthie, G. M. (2006). A framework for the physical development of elite rugby union players. International Journal of Sports Physiology and Performance, 1, 2–13.

Duthie, G. M., Pyne, D., & Hooper, S. (2003). Applied physiology and game analysis of rugby union. Sports Medicine (Auckland, N.Z.), 33, 973–991.

Freitag, A., Kirkwood, G., & Pollock, A. M. (2015). Rugby injury surveillance and prevention programmes: Are they effective? BMJ: British Medical Journal (Online), 350, h1587–h1587.

Fuller, C. W., Taylor, A. E., Brooks, J. H. M., & Kemp, S. P. T. (2013). Changes in the stature, body mass and age of English professional rugby players: A 10-year review. Journal of Sports Sciences, 31, 795–802.

Gabbett, T. J., Jenkins, D. G., & Abernethy, B. (2010). Physiological and anthropometric correlates of tackling ability in junior elite and subelite rugby league players. Journal of Strength and Conditioning Research, 24, 2989– 2995.

Gabbett, T. J., Kelly, J., Ralph, S., & Driscoll, D. (2009). Physiological and anthropometric characteristics of junior elite and sub-elite rugby league players, with special reference to starters and non-starters. Journal of Science and Medicine in Sport, 12, 215–222.

Gabbett, T. J., King, T., & Jenkins, D. (2008). Applied physiology of rugby league. Sports Medicine (Auckland, N.Z.), 38(2), 119–138.

Gamble, P. (2004). Physical preparation for elite-level rugby union football. Strength and Conditioning Journal, 26(4), 10–23.

Grobler, T. D. T., Shaw, B. S., & Coopoo, Y. (2016). Relative age effect (RAE) in male school-aged rugby union players from Gauteng, South Africa. African Journal for Physical Activity and Health Sciences, 626–634. Retrieved from https://journals.co.za/content/ajpherd1/22/Issue-22

Hopkins, W. G. (Producer). (2017). A spreadsheet to compare means of two groups. Sportscience. Retrieved from sportsci.org

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. Medicine and Science in Sports and Exercise, 41, 3–13.

Howard, S. M., Cumming, S. P., Atkinson, M., & Malina, R. M. (2016). Biological maturity-associated variance in peak power output and momentum in academy rugby union players. European Journal Sport Sciences, 16, 972–980.

Johnston, R. D., Gabbett, T. J., & Jenkins, D. G. (2015). Influence of playing standard and physical fitness on activity profiles and post-match fatigue during intensified junior rugby league competition. Sports Medica Open, 1, 18.

Johnston, R. D., Gabbett, T. J., Jenkins, D. G., & Hulin, B. T. (2014). Influence of physical qualities on post-match fatigue in rugby league players. Journal of Science and Medicine in Sport, 18, 209–13.

Jones, B., Till, K., Barlow, M., Lees, M., O'Hara, J., & Hind, K. (2015). Anthropometric and three-compartment body composition differences between Super League and Championship rugby league players: Considerations for the 2015 season and beyond. PloS One, 10, e0133188.

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., & Bangsbo, J. (2003). The yo-yo intermittent recovery test: Physiological response, reliability, and validity. Medicine and Science in Sports and Exercise, 35, 697–705.

Lewis, J., Morgan, K., & Cooper, S. M. (2015). Relative age effects in welsh age grade rugby union. International Journal of Sports Science and Coaching, 10, 797–813.

Lombard, W. P., Durandt, J. J., Masimla, H., Green, M., & Lambert, M. I. (2015). Changes in body size and physical characteristics of South African under-20 rugby union players over a 13-year period. Journal of Strength and Conditioning Research, 29, 980–988.

McCarthy, N., Collins, D., & Court, D. (2016). Start hard, finish better: Further evidence for the reversal of the RAE advantage. Journal Sport Sciences, 34, 1461–1465.

Phibbs, P. J., Jones, B., Roe, G. A., Read, D. B., Darrall-Jones, J., & Weakley, J. J. (2017a). Organised chaos in late specialisation team sports: Weekly training loads of elite adolescent rugby union players. Journal Strength Cond Researcher, Advance online publication. 1. doi:10.1519/ JSC.0000000000001965

Phibbs, P. J., Jones, B., Roe, G. A., Read, D. B., Darrall-Jones, J., Weakley, J. J., ... Till, K. (2017b). We know they train, but what do they do? Implications for coaches working with adolescent rugby union players. International Journal of Sports Science and Coaching, 12, 175–182.

Read, D., Weaving, D., Phibbs, P. J., Darrall-Jones, J., Roe, G. A., Weakley, J. J., & Jones, B. (2017). Movement and physical demands of school and university rugby union match-play in England. BMJ Open Sport and Exercise Medicine, 2, e000147.

Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. Journal of Sports Sciences, 18 (695–702), 695–702.

Taylor, K. L., Hopkins, W. G., Chapman, D. W., & Cronin, J. B. (2016). The influence of training phase on error of measurement in jump performance. International Journal of Sports Physiology and Performance, 11, 235–239.

Till, K., Cobley, S., O' Hara, J., Cooke, C., & Chapman, C. (2014). Considering maturation status and relative age in the longitudinal evaluation of junior rugby league players. Scandinavian Journal of Medicine & Science in Sports, 24(569–76), 569–576.

Till, K., Cobley, S., O'Hara, J., Morley, D., Chapman, C., & Cooke, C. (2015). Retrospective analysis of anthropometric and fitness characteristics associated with long-term career progression in rugby league. Journal of Science and Medicine in Sport, 18, 310–314.

Till, K., Jones, B., Emmonds, S., Tester, E., Fahey, J., & Cooke, C. (2014). Seasonal changes in anthropometric and physical characteristics within english academy rugby league players. Journal of Strength and Conditioning Research, 28(2689–96). doi:10.1519/JSC.0000000000000457

Till, K., Scantlebury, S., & Jones, B. (2017). Anthropometric and physical qualities of elite male youth Rugby League players. Sports Medicine, 47, 2171-2186. doi:10.1007/s40279-017-0745-8

Weakley, J. J., Till, K., Darrall-Jones, J., Roe, G. A., Phibbs, P. J., Read, D., & Jones, B. L. (2017). Strength and conditioning practices in adolescent rugby players: Relationship with changes in physical qualities. Journal of Strength and Conditioning Research. Advance online publication. 1. doi:10.1519/ JSC.0000000000001828