Abstract

The development of a youth team sport athlete is a complex process. This paper outlines challenges which may restrict the optimal balance between training and recovery and provide solutions to help practitioners overcome these challenges. To facilitate positive youth athletic development, training aims must be aligned between stakeholders to synchronise periods of intensified training and recovery. Within- and between-athlete variations in weekly training load must be managed and practitioners should attempt to ensure the intended load of training equals the load perceived by the athlete. Furthermore, practitioners should be cognizant of the athletes' non-sport related stressors to enable both academic and sporting pursuits. Whilst each of these challenges adds intricacy, they may be overcome through collaboration, monitoring and if necessary, the modification of the athletes' training load.

Introduction

The objective of youth athletic development is clear, "*develop healthy, capable and resilient young athletes, while attaining widespread, inclusive, sustainable and enjoyable participation for athletes of all levels*" (5 p.1). Whilst the goal is clear, it is not necessarily simple to achieve (38). Managing the training schedule of a youth team sport athlete is a complex process. This is in part due to the numerous stakeholders involved (e.g., school sport teachers, sports team coach), the need to encompass various types of training (e.g. technical, tactical, resistance training) and the participation within multiple competitions often across separate environments (e.g. club/school teams) (48,50).

A sufficient training stimulus is required to develop the technical/tactical skills and physiological capacities required to achieve success in sport (19,22), whilst inadequate prescription of training load will under prepare the athlete for the demands of competition (22). Despite this, a 'more is better' (with inadequate recovery) approach to training may predispose the athlete to a maladaptive training response (e.g., overtraining, overuse injury and burnout) (41). Previous research has found 20% of school/club level athletes experience non-functional overreaching at some point in their sporting career, whilst research in elite youth (12-17 years) soccer found the incidence to be 9% for girls and 27% for boys (17,41,64). Furthermore, 33% of girls and 60% of boys experienced multiple bouts of non-functional meaning a previous period of non-functional overreaching is a risk factor for a future bout (64). Multiple bouts of non-functional overreaching may ultimately lead to overuse injury or sporting burnout. Subsequently, coaches must adopt a holistic approach considering all elements of the athlete's training schedule rather than solely considering their own practice to optimise the prescription of training load (3). Recovery must be systematically integrated into the training schedule to prevent non-functional overreaching, with adequate recovery particularly important in youth sport due to unique factors such as growth and maturation increasing the amount of recovery time required to facilitate the growth process (6,64). This article explores the factors contributing to the challenge of this process as well as providing several solutions for facilitating the management of training load in youth team sport athletes.

Challenge #1: A scheduling tug of war

Whether it be for enjoyment or long-term sporting career ambitions, youth athletes frequently participate in multiple sports or for multiple teams within the same sport (48). The various weekly commitments of the athlete can spark a 'tug of war' scenario. This can be a consequence of separate and contrasting athlete focused training plans, goals, or applying a team focus as opposed to an individual athlete focus (50). Athletes should be exposed to periods of high training volume and/or intensity to provide a sufficient stimulus to provide a progressive overload, facilitating the development of technical and tactical skills (38,39). However, following periods of intensified or voluminous training, recovery must be implemented into the program to provide the athlete the opportunity to dissipate fatigue, adapt and avoid maladaptive responses such as overuse injury (41). Systematic planned periods of high training load, followed by intentional low training loads, to facilitate recovery and adaptations are likely absent, when multiple stakeholders are planning an athletes' development in isolation, with inherent competing demands (48).

Figure 1 displays a hypothetical week for an elite youth rugby union athlete, based on previous literature (28,50), highlighting the potential issues of a non-synchronised training schedule. Figure 1a presents the hypothetical training duration of school rugby, figure 1b presents the hypothetical training duration of academy rugby, and figure 1c presents the hypothetical training duration of other sports the athlete might participate in. Individually, the training durations do not appear problematic, with periods of high and low training, but when combined (figure 1d) these can become problematic. For example, the athlete participates in a school match on Wednesday afternoon (figure 1a) prior to other sports training in the evening. Given match play requires a longer period of recovery than training (53), a recovery session is incorporated by the school coach on the Thursday morning. However, the athletes' academy, unaware of the athletes' school match the previous day, continues with an unmodified training session including one hour of technical training and one hour of strength and conditioning. Academy training sessions have been shown to impose a greater load on the athlete in comparison to school training sessions (48), therefore potentially negating the benefits of the recovery session earlier in the day. The athlete returns to school training on Friday, 48 hours post-match with the school coach assuming the fatigue accrued from the match has largely dissipated (53). The athlete has not actually had the chance to recover from the match on Wednesday and enters the weekend fixtures with residual fatigue, compromising performance and potentially predisposing the athlete to injury (41,58).

In this scenario, it is not necessarily the overall training load that is predisposing the athlete to a maladaptive response, presented in figure 1d. Youth athletes with higher weekly training loads have been shown to have more favourable recovery-stress states in comparison to athletes with lower weekly loads (27). Therefore, it is likely to be the organisation of the training load across the week that might restrict recovery. The athletes' training schedule should be synchronised to allow adequate recovery. This should be integrated by all the teams associated with the athlete to prevent the unintentional accumulation of fatigue which may lead to performance decrement, non-functional overreaching, increased likelihood of injury (41,58), and/or prevent the athlete being able to undertake hard (higher intensity/higher load) training sessions when prescribed.

***** Insert figure 1 near here*****

Solution #1: ***Collaboration & Communication***

Recently there has been a call for all stakeholders to collaborate on managing youth athlete training schedules (3,7). The athlete and the athletes' parent(s) should ensure regular communication between the various coaches whereby training aims, volume and intensity can be aligned across the entirety of the athletes' program, based on the athletes' stage of development and stage of maturation. Match scheduling and participation can vary depending on the perceived importance of the fixture as well as the skill level of the opposition (1,46). By sharing fixture lists with each other, coaches can evaluate potentially demanding periods for the athlete and provide flexibility within their program.

In the above example, by being aware of the athletes' training and competition schedule, the respective coaches could plan in advance to structure the training week to include appropriate recovery. The athlete is scheduled to have four gym sessions however previous research has demonstrated two sessions to be sufficient to elicit positive adaptions in body mass, strength and power (63). Therefore, coaches could replace Monday and Thursdays post-match-play gym sessions with recovery sessions. Additionally, by planning long term, coaches could highlight periods of demanding training and align the training schedule accordingly. Such collaboration may increase the conduciveness of successive technical training sessions affording the athlete the opportunity to recover following intense training. For example, if the academy coach planned an intense training session on Thursday, the school coach could reduce the duration and/or intensity of the athletes' training sessions on Friday prior to the weekend's fixtures. By the end of the week, the athlete would still have completed multiple training sessions. However, the manipulation of session load, assisted by a structured and pre-planned meso/micro cycle may have increased the likelihood of the athlete training/competing in an optimal state for performance, development and enjoyment perspectives.

Challenges may arise when determining the importance of training sessions and fixtures as clubs and schools may naturally perceive their sessions/fixtures to hold the most importance, leading to a reluctance to modify their training sessions to accommodate training/fixtures not within their schedule. However, maintaining this stance will be non-beneficial for all parties and an athlete centred approach should be taken. A lack of multi-stakeholder planning, with the ability to provide flexibility to offer appropriate periods of recovery within the training program will impair performance (58) and put the athlete at risk of a maladaptive training response such as an overuse injury (41) in turn, rendering the athlete unavailable for selection for all sides. This is not only determinantal to both club and school sides but also directly contrasts the goals of youth athletic development as the athlete is no longer healthy and capable and sport participation is no longer enjoyable or sustainable.

Whilst collaboration between stakeholders may facilitate the management of the athletes' training schedule, including the athlete in this process may provide an important developmental and educational opportunity. Previous research has suggested that athletes should update a training diary, and record information about their training (i.e. sRPE and duration) as well as their fatigue/recovery status (47). Encouraging youth athletes to maintain a training diary may provide autonomy regarding their training and recovery whilst also giving them a sense of ownership, which in turn may increase their motivation (65). Although it may take time to educate the athlete on factors such as symptoms of overtraining, this process will empower the athlete and reduce the burden on athlete stakeholders.

Challenge #2: ***Individual variance causing 'organised chaos'***

Another challenge presented to practitioners is the within- and between-athlete variance in weekly training load (50). Previous research in youth rugby union has found weekly session-rating of perceived exertion (sRPE) load (mean ± SD; 1425 ± 545) to have a coefficient of variation of 10; ± 6% between athletes and 37; ± 3% within athletes (50). Whilst variation in training load between athletes is expected, as athletes within the same squad often participate for different teams within the same sport (3), a more surprising finding is the large week to week variation in within-athlete load. A key element influencing within-athlete fluctuations in weekly load is the uncertain competition schedule (50). Fixture lists are subject to change in youth sport due to circumstances such as fixture clashes, adverse weather and progression in cup competitions. Therefore, a youth team sport athlete may compete in three matches one week and no matches the following week, causing a large fluctuation in weekly load (50). These challenges can be exacerbated over a number of weeks, with random training patterns emerging (50), previously described as *organised chaos.* This term has been used owing to the definitions of 'organised' "*to make arrangements or preparations for an event or an activity*' and 'chaos' "*the property of a complex system whose behaviours is so unpredictable as to appear random*" (49 p.21). Practitioners must be cognizant of the varying and at times random training loads and cannot assume the athletes' weekly load is consistent (50). Acute rises in weekly training load have been reported to increase the risk of injury as the athletes' ability to recover is surpassed by the fatigue accumulated (22,30). On the other hand, athletes may suffer deconditioning during periods of restricted match play due to the reduction of load (22). Both scenarios are detrimental to athletic performance and whilst coaches must plan training in advance in accordance with a periodised structure, they must also be aware of potential within- and between-athlete deviations from the planned weekly load. Therefore, rather than sticking to the periodised training plan regardless of the athletes' current condition, coaches should be flexible and adapt training sessions in response to the athletes' training load e.g. incorporate a lighter training session if the athletes' recent training load is higher than expected. To gather information regarding the athletes' wellness and training load, coaches should monitor athletes on an individual basis.

Solution #2: *Individual Monitoring*

As the weekly load placed on the athlete will vary due to fixture cancellations or higher/lower than expected prescribed training loads, communication between stakeholders on its own may be insufficient to monitor individual variations in load. A reliable and cost effective way of monitoring internal training load is sRPE load, previously shown to be valid in intermittent team sports (13,31,33), as well as youth team sport athletes (55). The sRPE load requires athletes to provide a session duration to the nearest minute and a rating of intensity from a modified category ratio-10 scale (20). When using the sRPE load method to quantify internal load, practitioners must be aware of how long the measure remains valid. Ideally, sRPE load would be reported by the athlete in isolation and 30 minutes post exercise (21,60). However, this is a difficult task as coaches are not always present at sessions outside of their own practice to obtain sRPE loads from the athlete. Whilst sRPE load has been shown to be valid 24 hours post-session with a typical error of estimate (TEE) of 4.8% (49) and 8.3% (56) as well as 48 hours post-session (18), the TEE increased to 35.3% after 72 hours and 28.5% 1 week post-session indicating a lack of validity (49). Therefore, to obtain a valid and up to date quantification of the athletes' day by day internal training load, coaches could set up a monitoring platform (e.g. web-based questionnaire), which requires athletes to fill in all the activity they participated in over the previous 48 hours, providing a duration and rating of intensity.

Whilst collection of sRPE load may provide information relating to athlete training, the coach must also be cognizant of 'under recovery' influencing the athletes' readiness to train. Readiness to train may be evaluated through the combination of the daily wellness questionnaire (DW) (45), the profile of mood states questionnaire for adolescents (POMS-A) (47) and perceived recovery scale (PRS) (36). In a sample of 52 youth team sport athletes, the DW was shown to provide a measure of the athletes' overall wellness whilst the PRS, a simple 0-10 measure, was associated with the athletes' training load and match exposure (e.g. a lower PRS score was related to a high training load) (54). Furthermore, the POMS-A has been used to identify overtraining in elite youth Swedish athletes (34). Setting up communication channels between stakeholders and encouraging athletes to maintain a training diary as mentioned in solution #1, would reduce the burden of questionnaire administration meaning the athlete would not have to fill in each questionnaire for coaches individually. Instead, coaches could share the athletes' response to each questionnaire (sRPE load, DW and PRS) between each other or require the athlete to present their training diary prior to each session, increasing the efficiency of the athlete monitoring process.

Alongside pre-training questionnaires, athlete fatigue and readiness to train may be measured via physical monitoring tools. The counter-movement jump and plyometric push-up tests have been shown to be sensitive and reliable measures of lower and upper body neuromuscular function respectively (32,45,52). Additionally, a significant relationship has been found between decrements in a vertical jump test and back squat performance following fatiguing resistance training exercise (62), substantiating the use of the vertical jump test as a measure of readiness to training. Therefore, coaches could administer a combination of the DW, POMS-A and PRS questionnaires alongside the use of physical monitoring tools (e.g.

countermovement and vertical jump tests) to gain an understanding of the athletes' overall wellness and previous training load, subsequently evaluating the athletes' readiness to train pre-session. Coaches would then be able to be adapt sessions accordingly to optimise the periodisation of training.

Challenge #3: ***Coach vs. Athlete: Mismatch!***

Manipulating weekly training to optimise the prescription of load is one problem facing the youth team sport coach. However, the coach must also ensure their intended load aligns with the athletes' perceived load, as ultimately this will determine the athletes' response. Previous research identified a mismatch between coach intended and athlete perceived sRPE load (8,9,57). Youth soccer, rugby and field hockey athletes perceived sessions the coach intended to be easy, harder than the coach intended and sessions intended to be hard, easier than the coach intended (9,57). Training at higher than intended intensities can contribute to greater than anticipated levels of muscle soreness, associated with muscle damage (11,58). The residual fatigue experienced by the athlete can impair subsequent training sessions as the accrued muscle damage restricts anaerobic performance, high-speed running and distance covered at a lower intensity (2,10,11). As sRPE load has previously been associated with increased high speed running and total distance (23,24), the fatigue accumulated by athletes training harder than planned during intended easy sessions may hamper their ability to train at higher intensities during intended harder sessions. However, to maintain or improve the physiological capabilities, training must provide a sufficient stimulus to promote adaption or athletes are left at risk of deconditioning (22). Deconditioning may leave the athlete physically incapable of handling the stress placed upon them during the most intense periods of match play as well as during more demanding blocks of training, predisposing them to injury (22). Alternatively, if athletes train harder than intended during easy or recovery sessions their ability to recover will be surpassed by the accumulation of fatigue as the recovery incorporated into the training schedule is not eliciting the desired response, causing a maladaptive training response (41).

Solution #3: Modifying external training variables to achieve a desired internal response

External training load represents the physical work performed by the athlete during training or match play (e.g. total distance ran, high-speed running) whilst internal load is the biochemical and biomechanical relative stress response determined in combination with the athletes' individual characteristics (43). A greater dose of external load increases the metabolic energy cost and soft tissue force absorption/production of the athlete leading to a greater internal response (61). By understanding how the manipulation of external training variables influence sRPE load, coaches could structure training to achieve a desired internal response reducing the mismatch between coach intended sRPE load and athlete sRPE load. The total distance covered by the athlete during training has predominantly been identified to have the strongest relationship to sRPE load (43). A potential reason for the large relationship between total distance and sRPE load may be due to the duration element of the sRPE load calculation increasing the correlation to volume measures of external load, (e.g. as the duration of the session increases, the total distance of the session naturally increases), strengthening the association between sRPE load and total distance. Therefore, when looking to modify the sRPE load of an athlete, the coach could attempt to maintain training intensity and manipulate the duration of training, and in turn the external load placed on the athlete.

Manipulating session duration appears to be a simplistic solution, however, it may not always be possible due to factors such as structured training times or school timetabling. In such instance's coaches should alter session intensity to achieve a desired sRPE load, a more complex task to achieve. Previous literature has identified an inconsistent relationship between external training load variables and sRPE (5,12,24,40). Large relationships between total distance, high speed running, PlayerLoad (an arbitrary unit that is derived from three-dimensional measures of the instantaneous rate of change of acceleration, measured via a 100-Hz accelerometer (4)) and sRPE were observed in senior male Australian Rules football (5). However, correlations between average speed (m/min), high speed running per minute, PlayerLoad per minute and sRPE range from low to moderate in semi-professional male soccer and professional male rugby league (12,40). Additionally, small correlations were found between high speed running per minute, impacts per minute and accelerations per minute in professional male soccer (24). A potential reason for the inconsistent relationship between external training variables and perceptions of session intensity are individual factors such as playing experience and fitness levels, with both previously shown to influence sRPE (23). Additionally, sRPE is dependent on various sociological and personality factors integrated into a gestalt rating (25,44). Due to the multitude of factors influencing sRPE alongside the external training load it is currently too complex to predict internal response solely through prescription of external load. Further research is required to fully understand how these factors interact with external training variables to influence sRPE. Until such relationships are identified coaches may take sRPE during the training session to gather an understanding of how individuals are perceiving session intensity before altering the session if necessary.

From a resistance training perspective, the sets, reps, intensity, and recovery of a training session may be manipulated by practitioners to increase/decrease training load depending on the desired training outcome. Increases in training intensity (% 1 rep max [RM]) and volume (e.g. reps per set, number of sets per session) have been shown to increase sRPE (16,29,35) and decrease post-exercise power output, measured via a countermovement jump (29).

Training at a higher intensity may cause more severe corollary signals to be sent from the sensory motor cortex due to greater motor unit recruitment and firing frequency, leading to an increase in sRPE (29). On the other hand, a greater training volume is thought to cause a disruption in homeostasis and an increase in the accumulation of hydrogen ions (26). The accumulation of hydrogen ions may restrict muscle excitation and contraction coupling, which can decrease the individuals ability to produce power, causing a subsequent increase in sRPE (26). In contrast to field-based training sessions, a reduction in training duration may increase training load during resistance-based training sessions (29,35) if training volume/intensity is not modified. Increasing the work rate of a training session by reducing recovery time between sets has been shown to increase sRPE and endocrine response and decrease power output (29). Therefore, strength and conditioning practitioners may increase training intensity (% 1RM), volume (reps per set, number of sets) or work rate (reducing the recovery time between sets) to increase the training load of an athlete or vice versa to reduce the training load.

Challenge #4: ***The student athlete***

The student athlete undertakes a unique set of challenges brought about by the simultaneous pursuit of both academic and sporting achievements. The time commitments associated with participation in education alongside sports training is a key contributor in the accumulation of fatigue (15). As previously mentioned, fatigue can impair sporting performance (41,58), however, of equal importance is the detrimental impact it can have on education (15). Student-athletes reported fatigue to hamper their ability to focus during class as well as restrict the time they have available to complete school assignments (15). Difficulty in balancing both sporting and academic commitments can contribute to athletes prioritizing education or sport with success in one venture coming at the expense of the other (14,42). Student athletes who prioritize education and reduce sporting commitments sacrifice the benefits of increased sports training and jeopardise future sporting attainment. On the other hand, prioritising sports training at the expense of education may limit future study opportunities, holding implications for future careers, with career uncertainty leaving athletes vulnerable to anxiety (37). Therefore, processes must be put in place to provide student-athletes the opportunity to thrive in both a sporting and educational setting rather than one or the other.

Solution #4: ***Program malleability and athlete education***

The solution to managing the schedules of student-athletes and facilitating both education and sporting pursuits lies in the combination of program flexibility and the upskilling of the athlete. The coach's level of understanding and support of educational commitments has been found to be crucial in the athletes' (in)ability to combine academic and sporting ventures (15). As such, coaches must once again take an athlete centered approach, communicating with the individual to identify periods of heavy academic stress (exam timetables, coursework deadlines) before altering the athletes' training schedule to provide sufficient time to revise or complete assignments. Monthly meetings may be scheduled between relevant parties to discuss the athletes' upcoming educational requirements and sporting commitments. Subsequently, structures may be put in place to ensure the athlete is capable of meeting the demands of both pursuits.

As fatigue has been reported to be a causal factor in reduced academic performance (15), practitioners may reduce the load placed on athletes during periods of high academic stress. For example, by identifying academically demanding periods through communication with the athlete, strength and conditioning coaches could reduce the intensity or volume of a resistance training session to reduce the load placed on the athlete with the aim of reducing subsequent fatigue (29,35). The coach may then increase session load in the following weeks, during less academically demanding periods to facilitate progressive overload and physiological adaptation.

Despite this, the responsibility for facilitating multiple pursuits does not lie solely with the coach and the athlete must also commit to self-development. Student-athletes would benefit from training aimed at developing coping strategies, in particular those improving the ability to manage stress and pressure (15). Additionally, educating the individual on time-management skills or helping the athlete 'learn how to learn' (programs aimed at assisting the athlete in understanding the most efficient way to maximise their learning) would contribute to optimising the athletes' time management (15), circumventing the issues arising from their restricted time schedules.

****** Insert figure 3 near here******

Summary

The development of youth athletes from a sporting perspective is a complex process with coaches facing an array of challenges. Challenges include a scheduling tug of war, individual training load variance, a mismatch in coach and athlete sRPE load and managing academic and sporting schedules. To facilitate the optimisation of the youth athletes' training program, the athlete should be required to maintain a training diary whilst all of the stakeholders involved with the athlete should collaborate on a regular basis to share expected training/fixture schedules. Collaboration will allow stakeholders to determine more/less demanding periods of training, competition and academia, subsequently modifying the athletes' training schedule accordingly. Additionally, coaches should monitor athlete training loads, wellness and recovery states on an individual basis by obtaining the athletes' sRPE load for the previous 48 hours and by completing the DW and POMS-A questionnaires. Furthermore, practitioners may asses the athletes' readiness to train via the PRS questionnaire and through physical monitoring tools such as the countermovement jump test. If practitioners are unable to get such measures in person, online questionnaires have previously been validated in youth sport (49,56) and offer a viable alternative. Quantifying training load on a daily basis will allow coaches to monitor within and between athlete variations in load and ensure the load placed on the athlete aligns with the coaches intended training plan. Should the load deviate from the periodised plan, coaches will be able to modify training through a reduction in training duration (when possible) to increase/reduce the load placed on the athlete. If manipulating the training duration is not possible, coaches may obtain perceptions of intensity during training and if necessary, alter the session accordingly. These challenges and solutions are depicted in figure 2 and can be used to support the youth athlete.

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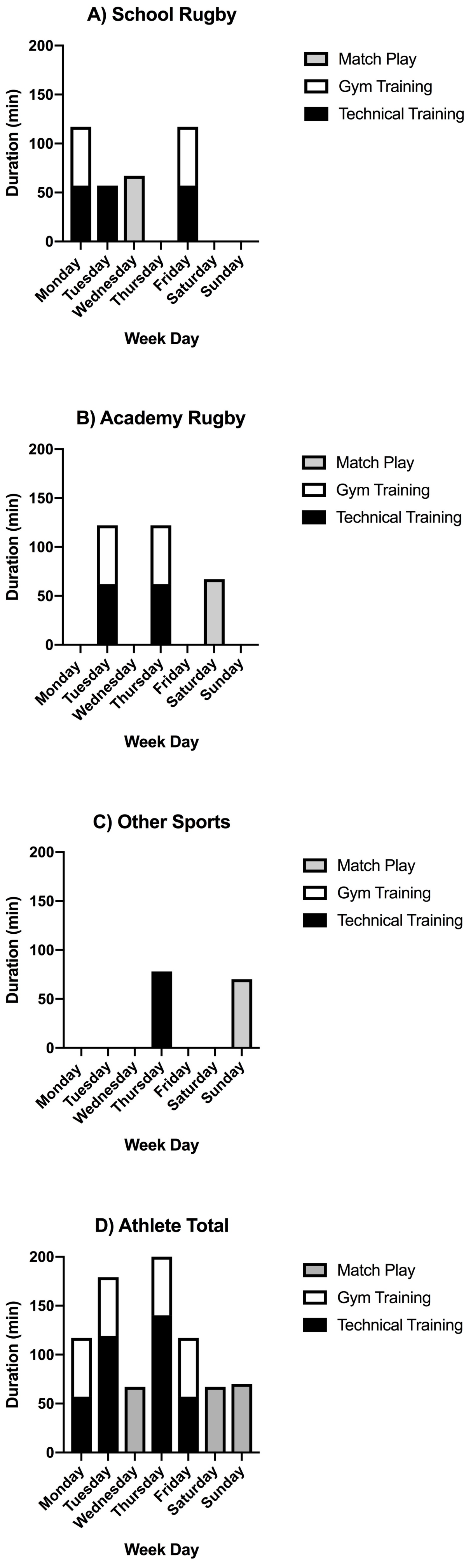
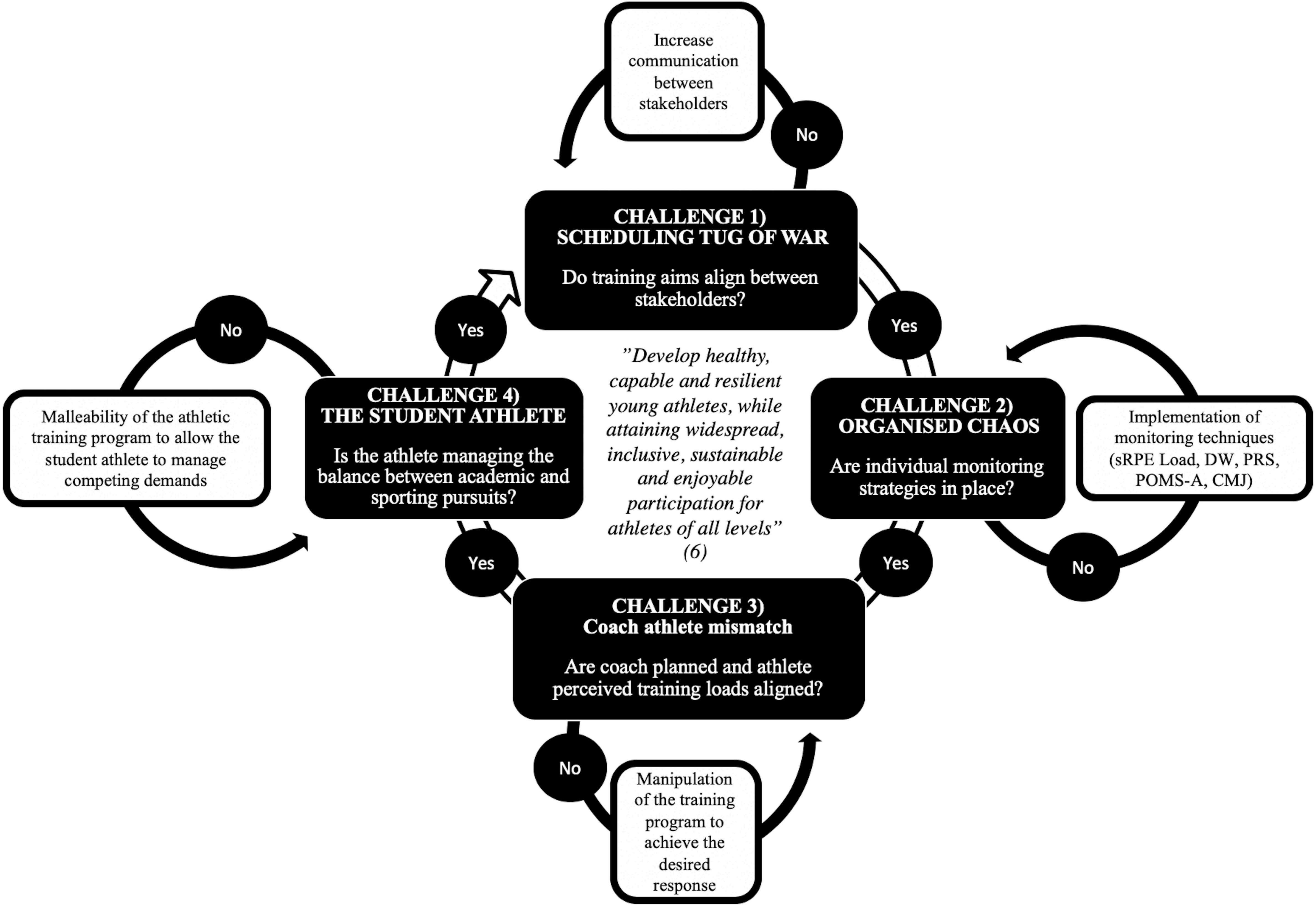
Figure 1; A hypothetical 7-day training schedule (minutes) for an elite youth rugby union player with school, academy and other sport commitments separated and then combined

Figure 2; The challenges and solutions to managing the development of a youth team sport athlete


A) School Rugby
B) Academy Rugby
C) Other Sports
D) Athlete Total
Duration (min)
0
50
100
150
200
Match Play
Gym Training
Technical Training
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Week Day


Increase communication between stakeholders
No
CHALLENGE 1) SCHEDULING TUG OF WAR
Do training aims align between stakeholders?
Yes
Yes
No
Malleability of the athletic training program to allow the student athlete to manage competing demands
CHALLENGE 4) THE STUDENT ATHLETE
Is the athlete managing the balance between academic and sporting pursuits?
"Develop healthy, capable and resilient young athletes, while attaining widespread, inclusive, sustainable and enjoyable participation for athletes of all levels" (6)
CHALLENGE 2) ORGANISED CHAOS
Are individual monitoring strategies in place?
Implementation of monitoring techniques (sRPE Load, DW, PRS, POMS-A, CMJ)
Yes
Yes
No
CHALLENGE 3) Coach athlete mismatch
Are coach planned and athlete perceived training loads aligned?
No
Manipulation of the training program to achieve the desired response