Chapter 2: Meeting a golfer's needs:

Needs analysis, profiling and coaching considerations in strength and conditioning

Abstract

This chapter considers the effective assessment, profiling, monitoring and coaching of golfers to meet their strength and conditioning needs. It is vital that the strength and conditioning (S&C) coach appreciates both the athlete and the sport specific demands. This chapter ensures that the S&C coach is equipped to adopt a multi-disciplinary approach to programming and fostering conducive training interventions and environments through which golfers can achieve their goals. A thorough overview of the underpinning needs of the athlete, the impact of the golfer's behaviours on internal load and the physiology, biomechanics and training demands required to succeed in the sport is provided. The chapter critiques a range of profiling protocols, their links to golf performance measures, such as clubhead speed, and their use in both laboratory and field-based settings. Furthermore, this chapter affords coaches and golfers an insight into the key questions a S&C coach should ask a golfer when working with them to establish effective, systematic S&C interventions.

Introduction

There has been a considerable shift in recent years from the predominantly technical and tactical perspectives on performance gains in golf (Glazier & Lamb, 2018). While the technical and tactical aspects are undoubtedly important to success, the modern golfer, possibly alongside their coach and a support team, is pursuing methods of improvement that were rarely used in the past. Wells and Langdown (2020) highlighted that golfers perceive the engagement with S&C as an opportunity to improve performance and reduce the risk of injury. In this regard, it is now common for elite amateur and professional golfers to employ fitness or S&C coaches as part of their support team. Sustained engagement in S&C may also place the golfer in a better position to adapt their behaviours to the various performance demands and constraints on the course.

The change in culture

Traditionally, golfers refrained from engaging in S&C based on the outdated misconceptions that these training modalities would decrease range of motion (ROM) / flexibility (Álvarez et

al., 2012). However, recent research has highlighted that, of a sample of 430 highly skilled golfers, 79.3% (341 of 430) disagreed that S&C would reduce flexibility (Wells & Langdown, 2020). As such, S&C is now seen as a fundamental tool that can help golfers of all levels succeed within the sport. These changes in perspective are likely due to the growing body of research supporting S&C for golf and underpinning practitioners' knowledge. In addition, statements from high profile golfers openly advocating the benefits training has had on their game increases the trust and the reputation of S&C for performance enhancement. For the S&C practitioner who is currently working with (or aspiring to work with) golfers, it is important to recognise the needs of the individual. For instance, research has highlighted that the top three qualities golfers looked for when working with a S&C coach were that they had 1) previously worked with golfers, 2) a developed understanding of the swing and 3) suitable qualifications (Wells & Langdown, 2020). It is advisable for a S&C coach to work closely with Professional Golfers' Association (PGA) golf coaches to develop further understanding of swing biomechanics, the 'coaching language', and the ability to create an intervention matched to the golfer's goals. It is critical that well-coordinated, interventions are put in place to optimise the golfer's availability and readiness to train. Lack of communication among the team of coaches can easily result in overloading the golfer's schedule with inappropriate training and practice volumes, thus increasing the risk of injury, overtraining and fatigue.

Optimising the golfer's availability to train and compete

Through a systematic and robust needs analysis process, it is possible to gain insight into the moderators that impact upon the golfer's daily, weekly, and monthly training load, and specifically, their internal load (the body's ability to cope with, and its response to, the prescribed external load). These moderators (Figure 1) should be highlighted as part of the discussions around the establishment of training environments conducive to effective functional adaptations and should include general health, nutrition and hydration, sleep and recovery strategies. It is the S&C coach's role to use the needs analysis to establish a systematic programme that is both organised and provides a prescribed plan with quality exercises, completed in the required quantities, to elicit the desired internal load following a critical analysis and understanding of the moderators impacting on the individual golfer. While this chapter is not focusing on the measurement of internal or external loads, it is important for the needs analysis to consider the moderators of the internal load, i.e., the body's psychophysiological response. The European Tour Performance Institute (ETPI) developed a theoretical Probability of Performance Impact model indicating the different benefits S&C could have on golfers' performance (see Chapter 8) (Brearley et al., 2019). The model

suggests that the greatest benefits from S&C provision would be through maximising the golfer's availability and readiness to play the game. This can be achieved by ensuring the moderators of load are optimised for each individual in order to reduce the risk of injury, susceptibility to illness and fatigue, and therefore maintain their S&C engagement. Consistent engagement allows the principles of training to be applied effectively through progressive overload and suitable rest, resulting in the efficient achievement of adaptations, and minimising the impact of reversibility. Suboptimal golfer behaviours will present opportunities for the S&C coach to educate and inform the subsequent training programme based on the golfer's current needs and development. S&C coaches should prioritise optimisation of the moderators of internal load as a goal of the S&C programme, alongside providing an organised, quality intervention with correct quantity to elicit functional adaptations.

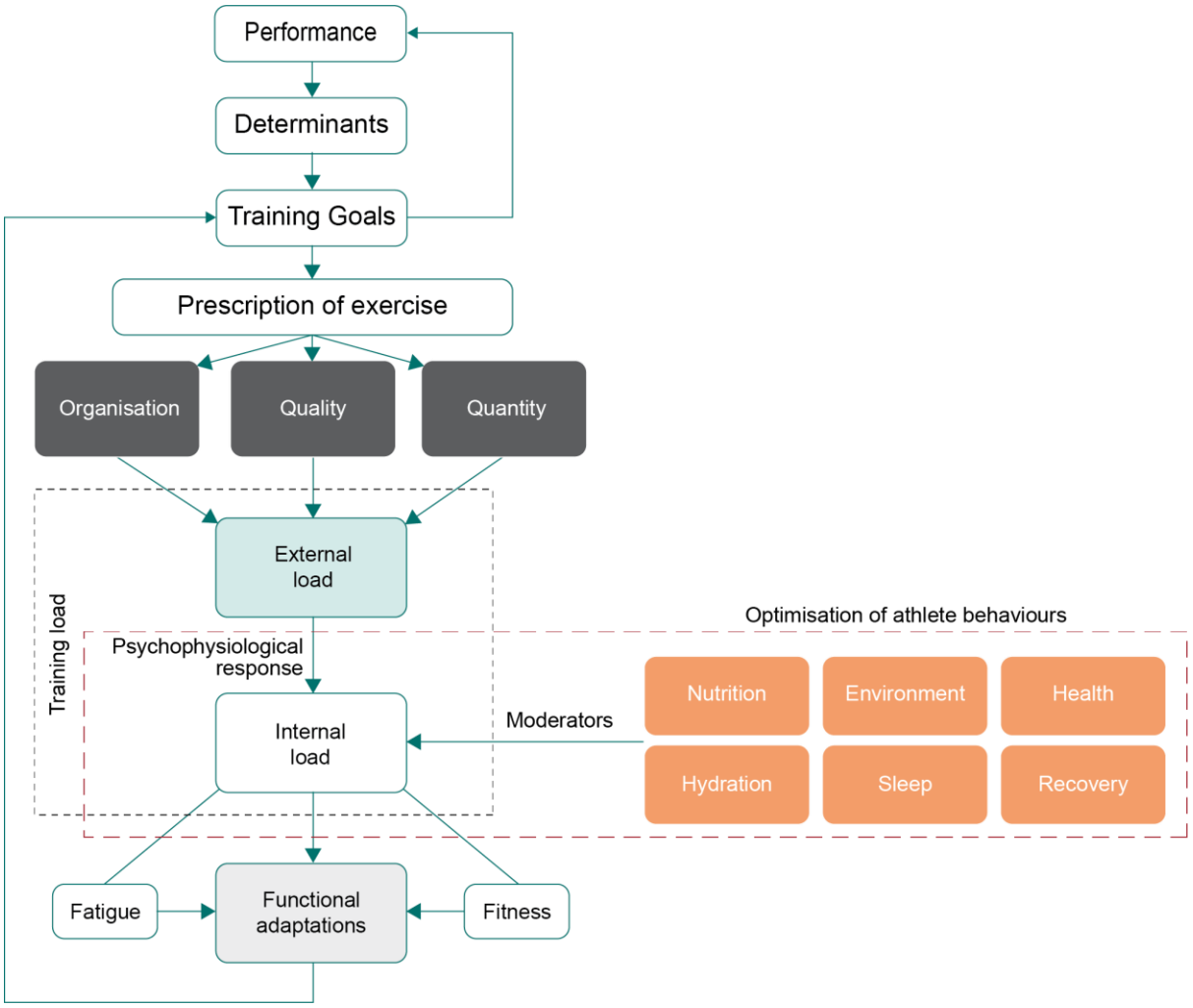


Figure 1. The theoretical framework of training load split into 2 measurable components: external (training load) and internal load (psychophysiological response). Adapted from Impellizzeri, Marcora and Coutts (2019).

Nb. *The figure visualizes how this is relevant to the systematic programming of exercises in response to the needs analysis process, the fitness-fatigue model, and the other characteristics which can moderate the internal response.*

From a needs analysis perspective, it is initially important to understand the demands of golf (Figure 1. 'determinants'). These decisions are advocated through recognising the demands of the swing and the stress that this can place on the body. As such, recognising the most common injuries within golf are of upmost importance (see Chapter 9). Increases in the collection of performance stats on professional and amateur tours / events, statistical methods for analysing the sport (Broadie, 2014), development of new technology, such as launch monitors (Stefanyshyn & Wannop, 2015), and an increased financial incentive for success at the elite levels (Farrally et al., 2003) has driven an increased understanding and influenced the approach taken in profiling protocols and how to elicit performance enhancements. As an example, this includes generating greater drive distances through training interventions (e.g., Alvarez et al., 2012; Bliss, McCulloch and Maxwell, 2015; Cummings et al., 2018) and measurement of impulse and vertical force production (e.g., Wells et al., 2019).

Coach's perspective: The coach-golfer relationship

Before coaches begin to apply their professional S&C knowledge, it is essential to understand that professional knowledge (i.e., coaching knowledge), interpersonal knowledge (i.e., relationships with golfers and the educational community) and intrapersonal knowledge (i.e., a coach's own reflections, ethics and coaching dispositions) are not independent of each other (Côté & Gilbert, 2009). Coaches need to understand the individual(s) in front of them. Having extensive professional S&C knowledge and conducting a needs analysis with a golfer is potentially redundant if coaches cannot effectively communicate their knowledge to, and with, the golfers they are coaching, in order to meet their needs. Here is where effective coaching is required. Understanding the needs of an individual, whether in a golf or S&C context, is paramount to being able to work effectively with them. Szedlak et al. (2015) reported that coaches' actions, values and the relationship the coach built with the athletes were three fundamentally important behaviours of successful S&C coaches. Coaches will need to reflect and adapt their practice to facilitate the golfer's achievement of their optimum performances and reduction of injury risk through effective coaching experiences.

Needs analysis: A multi-disciplinary approach

A needs analysis forms the ideal starting point when working with golfers of any level (see Figure 2). It allows coaches to identify the demands of the sport and the specific requirements for each individual within their S&C sessions and golf practice / performance. It should also take on the form of a multi-disciplinary approach to consider all aspects of sport and exercise science. When considering individual disciplines, the S&C coach must seek to establish ways in which a golfer is less likely to incur an injury. Additionally, the S&C coach should enhance performance variables that are associated with decreased scoring and, in the professional game, increased prize money. The disciplines and consideration that a S&C coach could include, but are not limited to, are:

- Anatomy and physiology: The demands that golf places on the golfer's body. A S&C coach can gain greater understanding of their resilience to these demands through the individual's current profiling test scores – e.g., force producing capabilities and joint ROM compared to normative data to allow a training programme to focus on the strengths and weaknesses as required. For instance, for a golfer to swing the club to the top of the backswing, it requires adequate mobility in the hips and thoracic spine. Indeed, research has suggested that the pelvis and torso rotate to approximately 49˚ and 98˚ in the backswing respectively (Chu, Sell & Lephart, 2010). It is important to recognise that the rotational values presented here are mean values with requirements varying among individuals. If this level of rotation is unattainable, the golfer may then produce a 'shorter' backswing or is forced to make compensations in their swing (e.g., by lifting the arms, standing out of posture, extending the trail knee, increasing radial deviation (wrist cocking), or flexing the lead elbow). Having a 'short' backswing may negatively affect the carry distance a golfer can achieve. Increasing the length of the backswing by 12 cm (as represented by the path of the hands) has been suggested to increase clubhead speed (CHS) by 2.7 mph (Mackenzie, Mccourt & Champoux, 2020). Therefore, alongside potential technical adjustments (where physical constraints have been overcome), a S&C intervention may support the golfer to meet their need for an increased length of backswing. Furthermore, golf coaches should consider the ball flight and liaise with the S&C coach on how the anatomy and physiology may be impacting this. The authors would not recommend the opposite approach whereby the S&C practitioner attempts to achieve arbitrary thresholds (e.g., 98˚ torso rotation) to produce a 'model swing'.

Aside from the golf swing itself, a round of golf can exceed four hours. However, it would be erroneous to assume that golf should be classified as an endurance-based sport. Blood lactate responses of 0.8–1.1 mmol/L, which are typically representative of resting levels, and peak heart rate responses below anaerobic thresholds have been recorded following the completion

of 18 holes, (Unverdorben et al., 2000). Indeed, Unverdorben et al. (2000) reported that golfers only reached 55.3 $\pm$ 9.1% of $\dot{V}O_2$Max during their round, which is obviously dependent on course topography. Given the requirements to protect the golfer from golf related injuries, whilst trying to enhance key performance measures such as CHS, the provision of S&C programmes should focus on these aspects rather than prioritising any endurance training.

- Training demands: Current and future training demands should result from appropriate assessment of the individual's training age, history and status and linked to the results of profiling tests. The systematic training programme should then be implemented to help the athlete meet the demands of golf and their specific needs / goal(s). Anecdotally, we know that there can also be increased demands placed on the golfer by themselves, golf coaches and parents (especially if they are juniors). This can lead to an increase in the number of balls hit within practice sessions. Langdown et al. (2018) highlighted that golfers engaged in a regional and national performance programme had large fluctuations in practice volumes, particularly around school holidays, such as Easter and summer. There are numerous factors that could elicit significant increases ('spikes') in a golfer's practice volume. For instance, a dip in form for a professional golfer may lead to an increase in time spent on the driving range (e.g., number of long game shots played) in an attempt to improve their performance prior to subsequent competitive rounds. With large spikes in volume and intensity providing cause for concern over injury risk, it is critical that sustained engagement in S&C is encouraged and made viable for golfers to protect them from such risks.

With increased engagement in S&C comes an increased athlete training load. Measures of training load can be through the external load (e.g., volume load lifted in the gym), and internal load (e.g., the perceived exertion required to complete the session). With large fluctuations in volumes seen in Langdown et al.'s (2018) performance squad sample (n = 111), it is evident that practice strategies have large inter- and intra-individual fluctuations. Average monthly total volumes can be dictated by the time available to the golfer, pressures external to golf (e.g., work, family or academic) and motivation to practice. With better weather comes an increase in short game and putting practice durations. In contrast, with poor weather and reduced daylight hours, during the autumn and winter months there is an increase in long game practice (Langdown et al., 2018). With this in mind, Penner, (2003) highlighted that the force created during the impact between the club and ball reaches 10 kN (1020 kg). With the hands and wrists being the first anatomical location to experience the result of this impact between club and ball it is unsurprising that injuries in this area are common (Murray et al., 2017). With many shots being played from range mats, increasing the forces experienced through the wrists in comparison to practice on softer turf, it is important that both S&C

coaches and PGA Professional golf coaches collaborate in the facilitation of monitoring and management of training and practice volumes (e.g., through structuring effective practice schedules). Considerations should also include the impact of other external factors (e.g., other physical activity besides golf, non-golf stress / pressures etc.), monitored through athlete self-report measures such as wellness surveys and training load logs (including volume / duration and intensity). As previously mentioned, to increase tolerance against the demands of high volumes of practice and tournament play, golfers should engage in a systematic and well-conceived S&C programme.

- Biomechanical demands: While hierarchical or deterministic models can provide us with the biomechanical understanding of the golf swing and the influences on ball flight (e.g., see Hay, 1993), S&C coaches need to focus their attention on which aspects are within their control and remit within the gym environment. Glazier and Lamb (2018) stated that while these hierarchical models can provide information about performance (i.e., ball flight physics), they are limited in their ability to provide information on what the body is doing to achieve the shot outcome. They argue that much of the golf research that looks at, for example, peak values of a movement variable (e.g., peak angular velocity of the pelvis / torso) does little to inform coaches of what is really occurring at a coordination and motor control perspective.

Each golf swing places a significant stress on the body, and when considered over time, the cumulative load theory (see Kumar, 2001) suggests that repeated loading through the golf swing, with high forces, increases the overall stress experienced by the golfer's body, which can damage musculoskeletal tissues. For example, compression forces in the spine are in excess of 6.5 (Lim, Chow & Chae, 2012) and 8 times body weight (Dale & Brumitt, 2016) immediately after impact, or 6.1 kN (621kg) and 7.6 kN (773 kg) when an amateur and professional player, respectively, hits a 5-iron (Hosea & Gatt, 1996). Shear forces, although not as large as compressive forces, are also present within the swing with anterior-posterior and medio-lateral loads peaking during mid-follow through at ~1.6 and 0.44 times body weight, respectively, when using a driver (Lim, Chow & Chae, 2012). As such, the spine is another common site of injury within golfers (Murray et al., 2018) and although the lumbar spine in particular is able to cope with these forces, junior golfers are particularly susceptible to defects in the pars interarticularis (e.g., spondylolysis and spondylolisthesis) (Brearley et al., 2021). For older golfers, the spine will degenerate with age and lose its shock-absorbing capabilities (Hosea & Gatt, 1996), leaving older golfers more susceptible to injury. It would be advisable, for S&C interventions to prioritise exercises that develop strength and mobility in and around this region. The following exercises may be advantageous in this regard:

- Hip mobility (e.g., 90-90 rockovers and figure 4 stretch)
- Trunk mobility (e.g., open book stretch and elbow reach backs)
- Anti-extension (e.g., roll out and anti-extension overhead press)
- Anti-rotation (e.g., Pallof press and plank rows or pull through variations)
- Anti-lateral flexion (e.g., overhead Pallof press or exercises with added perturbation, such as offset step ups).

With a growing interest for golfers to increase drive distance, the interaction between the golfer and the ground during the swing is an important consideration for S&C. Highly skilled golfers have been shown to generate >1.6 times their body weight in ground reaction forces (GRF) when hitting a driver, with these vertical GRF (vGRF) significantly related to CHS (Han et al., 2019). Therefore, S&C interventions and profiling procedures targeting vGRF are preferential (e.g., vertical jumps and isometric mid-thigh pull; Wells et al., 2018, 2019).

- Nutrition and hydration demands of the activity: These demands can be based on the climate in which the golfer is training (usually an indoor environment), the typical conditions for competition, as well as current habits and behaviour modification through monitoring of the individual over time. Nutrition and hydration are two of the moderators of internal load (Figure 1), and, although beyond the scope of this chapter, assessing and optimising strategies here, to remain fuelled and hydrated, can allow more effective training adaptations and an optimised psychophysiological response to prescribed exercises in a given S&C programme.

- Athlete monitoring: While there are protective benefits of training for golf, the individual needs to have an awareness and understanding of how to monitor fatigue, wellbeing and performance. It is critical that the golfing population embraces lessons learned from other sports in athlete monitoring. Maintaining training, practice, tournament, and wellness logs allows coaches to assess acute training status (i.e., how they present to each session as an individual in comparison to their norm or optimal state (i.e., readiness)) and longer-term readiness. Measures can include, but not limited to, energy levels, perceived recovery from previous training, muscle soreness, impact of menstrual cycle (for female athletes), and, in line with the psychological demands of each session, their motivation to train, and non-golf related stress etc. Athlete self-report measures are a useful addition to any systematic training to allow both acute and chronic alterations to the frequency, intensity, and volume of interventions across the completion of a periodised plan. A lack of measurement here leaves uncertainty over the appropriateness of the application of training to that individual and their needs on each specific training (and rest) day.

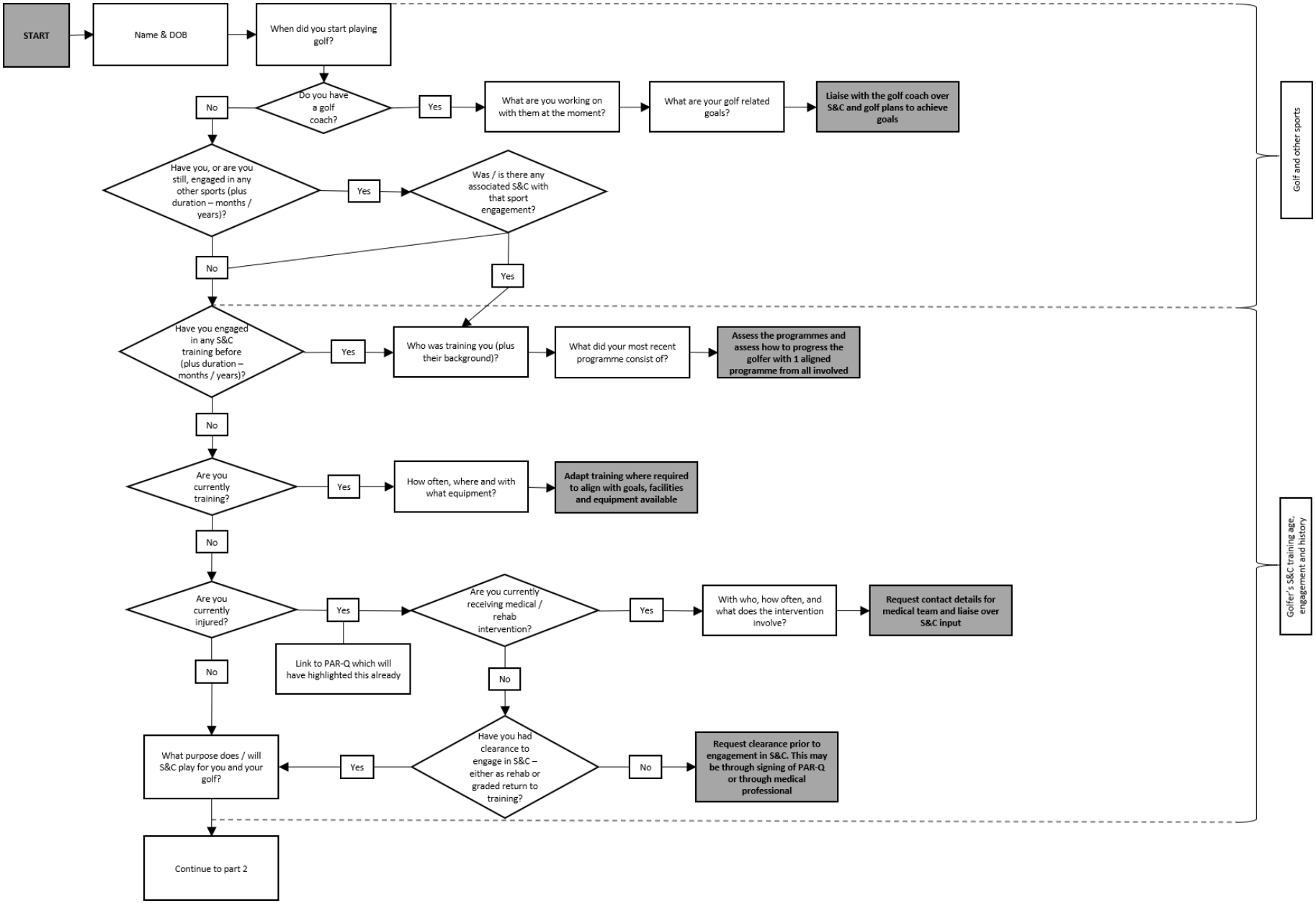
- Goal(s) of the individual golfer: Arguably the most important area for the golfer. Recognising the needs of the golfer is important in developing specific goals, however small or large these may be. It is the role of the coaches to ensure discussions take place to agree on suitably structured goals and to plan for all aspects of sport and exercise science to feed into this process (where appropriate). For instance, it may be that you are delivering S&C provision to a junior golfer to achieve longer term goals of reducing the risk of overuse injury and to enhance specific process goals and ultimately, performance goals. However, to attain these longer-term goals, the player will need to engage in the training programme set for them. The player and S&C coach should discuss and agree a realistic number of sessions per week that, alongside other physical activity loads, should be completed to help achieve the long-term goal(s).

There are other areas of sport and exercise science that may be considered along with the list above and S&C coaches may also find themself working alongside other professionals to create the needs analysis and a plan to reach a specific goal (e.g., sports medicine professionals where a golfer is injured and returning to training). When working with a golfer in a S&C environment it is critical that coaches understand them from a holistic perspective as an individual athlete. Agreement must be reached on the goals to be set and achieved and how this aligns to the demands of their golf.

Conducting a needs analysis

In scenarios where a S&C coach is working with any level of golfer, the programme goals must be to prescribe exercises that optimise the psychophysiological response (i.e., internal load) to elicit adaptation in the body in relation to their training goals. With the golfer performing S&C sessions systematically, adaptations will occur through changes at a cellular level (through functional capacity, structure and metabolic processes), and in the tissues, organs and the body's functional capacity, all of which lead to enhanced muscular activity (Viru & Viru, 2000). To achieve targeted adaptations, the planning of S&C interventions must reflect the needs analysis process coaches undertake with the golfer. This process initiates the formation of a relationship between the demands of the sport, the coach, the golfer, and their goals. It acts to establish factors such as training age, access to facilities / equipment, availability to train, injury, and health history (dealt with through a Pre-Activity Readiness Questionnaire (PAR-Q)), goals, motivation etc. (see Figure 2). Testing of adaptations through specific profiling tests (see 'Physical profiling' section) will allow for alterations in the exercise intervention to be administered. In this regard, the first session with an athlete can often provide a lot of

information to guide the systematic planning of the S&C interventions. Gathering this information can be done through discussion with the golfer and their support team (including parents for junior golfers) as well as assessing their profiling results and any monitoring data available to the coach to establish their current training status. Figure 2 provides a framework to ensure coaches can gather the initial information they may need through a flow of the key questions to prompt an extensive, but not exhaustive, needs analysis in golf.


START
Name & DOB
When did you start playing golf?
Do you have a golf coach?
No
Yes
What are you working on with them at the moment?
What are your golf related goals?
Liaise with the golf coach over S&C and golf plans to achieve goals
Have you, or are you still, engaged in any other sports (plus duration – months / years)?
Yes
Was / is there any associated S&C with that sport engagement?
No
Yes
Have you engaged in any S&C training before (plus duration – months / years)?
Yes
Who was training you (plus their background)?
What did your most recent programme consist of?
Assess the programmes and assess how to progress the golfer with 1 aligned programme from all involved
No
Are you currently training?
Yes
How often, where and with what equipment?
Adapt training where required to align with goals, facilities and equipment available
No
Are you currently injured?
Yes
Are you currently receiving medical / rehab intervention?
Yes
With who, how often, and what does the intervention involve?
Request contact details for medical team and liaise over S&C input
Link to PAR-Q which will have highlighted this already
No
No
Have you had clearance to engage in S&C – either as rehab or graded return to training?
No
Request clearance prior to engagement in S&C. This may be through signing of PAR-Q or through medical professional
Yes
What purpose does / will S&C play for you and your golf?
Continue to part 2
Golf and other sports
Golfer's S&C training age, engagement and history

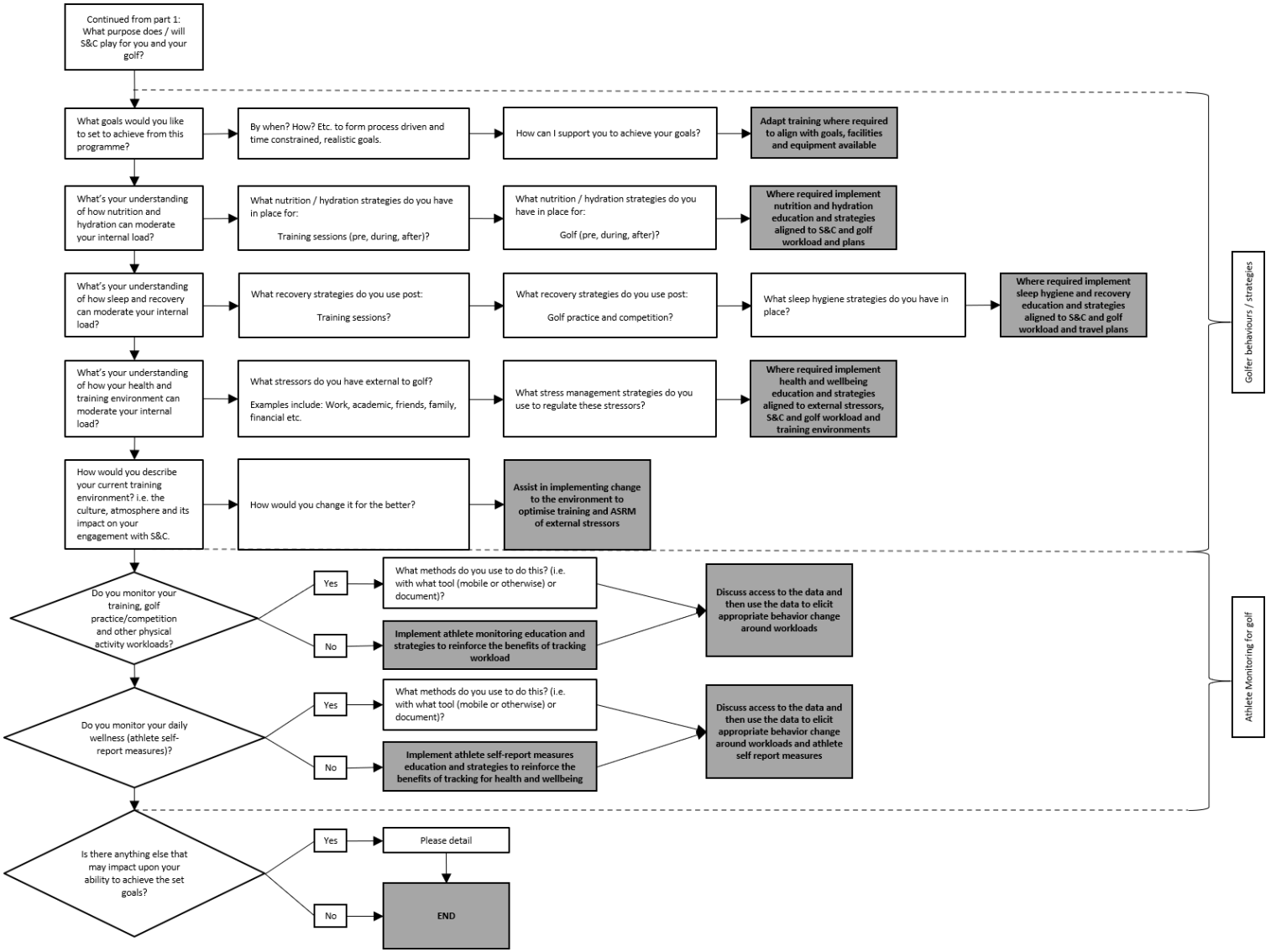


Figure 2. A needs analysis template for strength and conditioning coaches working with golfers.

Physical profiling

Having established the underpinning demands on the golfer (e.g., training loads from other sports, availability, impact of their current behaviours – moderators of internal load), the S&C coach can then look to physically profile the golfer. This allows the S&C coach to establish a baseline of physiological attributes within the selected tests. This baseline helps to identify areas of weakness that can be addressed through physical interventions. For example, if a golfer demonstrates undesirable results on an isometric mid-thigh pull or a repetition maximum test, a key focus for an intervention would be to target an increase in strength in line with the training goals. Profiling also facilitates the monitoring of progression while encouraging increased engagement through accountability for the golfer in the knowledge that post-intervention testing will take place to monitor any changes in physical performance. It is important for a S&C coach to match the demands of the sport to the tools they have available to profile the golfer ensuring that there is a strong rationale for the collection and use of each specific metric. At this point, it is worth noting that the monitoring of maturation is critical when working with junior golfers to allow insights into their growth, years from peak height velocity and to control for this when comparing profiling results over time (see Chapter 6).

Whichever profiling tools a coach chooses to use with a golfer, it is essential that the S&C coach has a clear and defendable rationale for utilising these profiling procedures. Not only should this rationale be supported by research, but it is also important to clearly explain the links between the profiling procedure and the demands of golf performance. Additionally, it is essential to ensure robust testing protocols are used to allow for accurate comparisons across pre- and post-interventions. Only when measurement reliability and validity are achieved does the data provide effective evidence to feed into the needs analysis and determine the new goals for training.

Range of motion and movement assessments

It is our belief that, where appropriate, tests to establish a golfer's ROM should be used, but coaches should not be fixated on measuring every joint used in the golf swing or try to predict specific swing characteristics based on a physical limitation. Instead, the PGA Professional and S&C coach should work together to establish the causes of undesirable ball flights, impact factors, swing faults and potential movement assessments to identify any ROM limitations.

Coach's perspective: The sequence of detection

When analysing the golfer, it is preferential to work from the ball flight backwards:

Ball flight → Impact factors → Swing mechanics

Here we show a hypothetical example of the ways in which a PGA Professional and S&C coach, working together, may seek to assess the ROM in a golfer.

Case study: Right-handed golfer

1. Ball flight: The golfer lacks distance with their driver and long irons.

2. Impact factors: CHS is likely to be the issue as it accounts of 75% of the variance in ball speed (Sweeney et al., 2013).

3. Swing mechanics: The golfer appears to have limited rotation in their thoracic spine and their club is short of horizontal at the top of the backswing.

4. Assessing ROM: Given the short backswing and limited thoracic rotation in the swing, a S&C coach may wish to assess the ROM using the seated thoracic rotation test. Golfers who perform better in this test have greater spine rotation at the top of the backswing (Gould et al., 2021).

5. Limitation found – the S&C coach can provide interventions to increase ROM. Where no limitation is found – the PGA Professional can provide technical interventions to increase the length of the backswing.

The sequence of detection offers great value when assessing ROM, especially compared to assessing the full body before observing the golf swing. Therefore, rather than predicting what movements may occur in the swing based on the results of a full screening battery, coaches could simply observe the ball flight and golf swing and target the movement assessments that may be of relevance to the golfer's and PGA Professional's technical goals. Additionally, the S&C coach should consider focussing more on observing and developing effective movement patterns within the gym environment, thus allowing safe and progressive S&C to take place, in line with the individual's goals.

As an example, it has been claimed by the Titleist Performance Institute that if a golfer is unable to perform an overhead squat (OHS), it is 'almost impossible' for them to maintain their posture in the swing (Rose, 2013). Despite these claims, evidence from Langdown (2015)

suggests otherwise given that the overhead squat was only a small significant predictor of loss of posture in the golf swing. Specifically, Langdown (2015) reported that at the top of the backswing only 30% of the variance in upper body lift is attributable to the measure of OHS torso lean when profiling the golfer using this test. At impact even less of the variance could be accounted for. The highest variance was OHS torso lean accounting for just 11.9% of spine flexion / extension (i.e., loss of posture angles in the torso at impact). Furthermore, Langdown (2015) used an intervention to significantly improve the OHS depth but reported no significant changes to subsequent in-swing posture. This emphasises that S&C is only one aspect of performance enhancement and that, where new strength / ROM / speed etc. goals are achieved in the S&C environment, it is vital that golf coaching supports the application of these gains into the swing and performance where appropriate. Research tells us that a delay often exists between improvements in physical capacity and its translation to improved sport-specific performance (Suchomel, Nimphius & Stone, 2016). For example, Alvarez et al. (2012) reported significant gains in muscle strength and power after six weeks of training, but associated golf measures did not significantly improved until after 12 weeks.

Vertical jumps

The interaction between the ground and the golfer is fundamental in producing a golf swing and maximising this interaction can lead to increased CHS and distance gains. Although both medial-lateral (left-right) and anterior-posterior (forwards-backwards) GRF affect swing mechanics, the greatest magnitude of force is produced vertically (Lynn & Wu, 2018;). Indeed, these vGRF are typically very large (>2.5 times body weight) for golfers who achieve long drive distances (e.g., >300 yards) (Lynn & Wu, 2018). Exercises such as the countermovement jump (CMJ) and squat jump (SJ) are commonly used to profile golfers given that these are focussed on producing vGRF. Research has highlighted significant relationships between CHS and both CMJ height and SJ height (Hellström, 2008). This is advantageous in applied settings as jump height is easy to measure through contact mats or from mobile applications that have been validated against force platforms (Balsalobre-Fernández, Glaister & Lockey, 2015). Unfortunately, solely relying on jump height as a metric is problematic. Jump height is affected and thus confounded by the mass of the golfer. For instance, if two golfers (with masses of 70 kg and 85 kg) both jumped 0.3 m, it is evident that the 85 kg golfer needed to produce greater vGRF to attain the same jump height as the 70 kg golfer. Applied data (Wells et al., 2022) assessed the relationships between 50 highly skilled golfers' CHS and CMJ height, peak force, average power, peak power, force at zero velocity, net impulse and positive impulse. Each variable presented strong significant relationships with

CHS, apart from jump height which was not statistically significant. This is in contrast to Hellström (2008) and therefore raises questions as to the validity of using jump height as a metric when profiling golfers. Specifically, although research has found significant relationships between CHS and jump height, the authors recommend that S&C practitioners consider the use of other metrics to ensure validity.

In this regard, peak power in a CMJ and SJ are often utilised as an alternative profiling metric, especially given that Hellström (2008) reported strong significant relationships with CHS. There is a general belief that power is a cause-and-effect variable. For instance, if a golfer generated greater power in a vertical jump, it may be assumed that there would also be an increase in their jump height. However, a more powerful golfer in a jump test may not necessarily jump higher (Table 1).

Table 1: The average power, mass, relative power and jump height in a countermovement jump for two golfers.

	Golfer A	Golfer B
Average power (W)	2010.12	1344.87
Mass (kg)	90.02	70.93
Relative power ($W.kg^{-1}$)	22.33	18.96
Jump height (m)	0.25	0.31

As seen in Table 1, golfer A has a greater average power, a larger mass and greater relative power (average power / body mass) than Golfer B, but a lower jump height by 0.06 m (6 cm). It is essential that practitioners recognise that power does not directly cause a change in jump height. Consequently, it is recommended that impulse (which is the force generated over a given duration [force x time]) is utilised when profiling golfers (Knudson, 2009; Winter et al., 2016).

Research from Wells et al., (2018) reported a strong significant relationship between highly skilled golfers' (handicap ≤5) CHS and positive impulse generated during a CMJ and SJ. Indeed, 37.9% of the variance in Challenge Tour golfers' CHS can be accounted for by CMJ positive impulse (Wells et al., 2019). However, the investigations of Wells et al., (2018, 2019) utilised force plates which are not always readily available to practitioners. Where a S&C coach only has a jump height mobile application and a set of scales available, inverse

dynamics has been suggested as a valuable method to calculate net impulse (Wells et al., 2022). Here, a hypothetical example of a golfer who jumps 0.35 m and has a body mass of 73.3 kg is used to demonstrate how this could be applied in practice:

1. Calculate the take-off velocity of the centre of mass:

$$\text{Take-off velocity} = \sqrt{(\text{Jump height} * (2 * \text{Gravity}))}$$

$$\text{Take off velocity} = \sqrt{(0.35 * (2 * 9.81))}$$

$$\text{Take off velocity} = 2.62 \text{ m.s}^{-1}$$

Note: gravity is always 9.81 m.s^{-2} and jump height is always in metres not centimetres for this calculation.

2. Calculate net impulse:

$$\text{Net impulse} = \text{mass} * \text{Take off velocity}$$

$$\text{Net impulse} = 73.3 \text{ kg} * 2.62 \text{ m.s}^{-1}$$

$$\text{Net impulse} = 192.08 \text{ N·s}$$

The calculation of net impulse is of great value to the practitioner since this is easily accessible and has a strong relationship with CHS. When considering the examples in Table 1, the net impulse is 199 N·s for golfer A and 175 N·s for golfer B.

As a benchmarking guide for S&C coaches using the above equations, the authors have observed mean values for net impulse of ~180 N·s and ~190 N·s for highly skilled male (handicap <5) and Challenge Tour golfers, respectively.

Coach's perspective: Assessing clubhead speed, ball speed and distance

While this section is focussed upon the profiling within a S&C environment, it is important to note that CHS, ball speed and distance testing also needs rigorous assessment methods to allow accurate analysis of the impact of S&C on drive performance measures. In this regard, here we present a method for maintaining reliability in testing:

1. Use a launch monitor where possible and consider the inherent measurement error for the specific make and model of the system being used (Leach et al., 2017).
2. Set-up ensuring the alignment and target selection are known to the golfer.
3. Ensure the golfer performs a standardised warm-up to maintain reliability of testing.
4. Ask the golfer to hit three drives as if playing a par five tee shot – i.e., aiming for maximal distance while maintaining accuracy to hit the fairway. Ensure 60 s rest is taken between each shot.
5. Ask the golfer to play three maximal drives with the only concern being maximum CHS. Ensure 60 s rest is taken between each shot.
6. Record the highest CHS, ball speed and distance from each condition to demonstrate results from maximum effort and controlled shots.

Run this protocol pre-intervention alongside any profiling where relationships are to be drawn to CHS, ball speed and distance. Then repeat post-intervention or before any major amendments to training programmes to understand S&C's impact.

Repetition maximum assessment

The most utilised method for assessing maximum strength is a repetition maximum (RM) test where the athlete (under qualified supervision) completes the chosen number of reps at an increasing load, with adequate rest between sets, until failure. Where >1 rep is used in the assessment, calculations are performed to estimate 1-RM, the values of which can then inform programme design and setting of loads for specific exercises. Research that links RM testing to golf has reported significant relationships between CHS and the load lifted in a 1-RM back squat (Hellström, 2008). Additionally, Parchmann and McBride (2011) reported that the relative load (load lifted / body mass) lifted in a back squat significantly related to golfers' CHS, supporting the notion that strength is an important component in this regard. This is of no great surprise given the aforementioned suggestion that the greatest magnitude of GRF are in the vertical direction (Lynn & Wu, 2018). However, conducting a RM test is only of value if the golfer can execute the lift proficiently and safely. As such, the limitations in a golfer's ability to

perform a RM test in, for example a back squat, may be masking the true relationship between strength and CHS. From a practical standpoint, if the S&C coach is only able to assess strength through a RM test (due to limited access to force plates), it is essential to initially develop the golfer's lifting technique through an intervention. Once the golfer is proficient in their technique, this will provide a better representation as a profiling tool. Where golfers are unable to use a direct 1-RM testing, a predicted 1-RM can be calculated from the number of reps at an appropriate weight where >1 rep can be completed. Typical alternatives include a 3-RM through to 10-RM predictive test.

There are some notable considerations / disadvantages of using a RM test when assessing golfers. For instance, Stone et al., (2019) suggested that these are time consuming and fatiguing. This is especially true where the goal is to test maximal strength (1-RM) as opposed to predictive tests (see Niewiadomski et al., 2008). A further consideration for the S&C coach is the standardisation of the squat depth as it is easier to lift a greater external load when reducing the depth of the squat. Ensuring a consistent squat depth (e.g., thighs parallel to floor) over each repeat testing session controls for this and increases the confidence that successful lifts of greater external load are due to physiological adaptation.

Isometric mid-thigh pull

Given the limitations with RM tests, alternative methods such as an isometric mid-thigh pull (IMTP) can be employed. The IMTP pull is utilised extensively by S&C researchers and coaches to measure peak force and rate of force development (RFD). Evidence has highlighted that peak force generated in an IMTP has a strong significant positive relationship with 1-RM back squat strength (McGuigan et al., 2010; Wang et al., 2016). Furthermore, research has reported a significant positive relationship between highly skilled golfers CHS and IMTP peak force (Wells et al., 2018). As guidance, mean IMTP peak force values of ~1600 N and ~2100 N have been reported for category-1 and Challenge Tour players respectively (Wells et al., 2018, 2019). Please note that these values represent average values for different skill levels and depending on the training goals, a golfer and their S&C coach would likely want to exceed these. There have also been suggestions that developing a golfer's ability to enhance RFD would be advantageous for generating CHS (Read & Lloyd, 2014). Whilst theoretically this appears plausible, research has highlighted that measuring RFD during an IMTP is unreliable (Wells et al., 2018), with the authors strongly cautioning against the use of this metric. It is appreciated that IMTP testing does require access to force plates and that this may prohibit widespread use. However, where they are available, S&C coaches should consider the following applied setup: Setting up an isometric rig can be performed without a

Smith Machine by using a squat rack instead. In this scenario the ‘J-hooks’ can be turned upside down and pulled against with an Olympic bar. This is further applicable if heavy resistance bands are used to attach the Olympic bar to a ‘pull-up’ bar at the top of the rack, meaning that the athlete does not have to support the weight (Figure 3).

Figure 3. A gym-based set-up of an isometric mid-thigh pull.

There are advantages of using an IMTP set-up (when available), to establish deficits in vGRF production, over RM testing. With the IMTP, technique is less likely to confound the results. Additionally, golfers are more likely to engage in an IMTP assessment, as there is reduced muscle soreness, less fatigue affecting the rest of the session and they may perceive this as a safer alternative compared to maximally loaded lifts (Stone et al., 2019). These advantages have led to the IMTP being employed by organisations such as England Golf and the European Tour to objectively profile golfers.

Medicine ball (MB) throws

It is very common for S&C coaches to use MB throws with golfers given that there is an element of visual similarity with the golf swing. Whilst it would be erroneous to select

assessments purely on this basis, research has highlighted significant relationships between various MB throws and CHS. Gordon et al., (2009) reported a significant relationship between a standing rotational MB throwing distance and CHS in adult golfers. Results from Read et al. (2013) supported this with significant relationships between both a standing rotational MB throw and seated MB chest throw with CHS. These findings were also observed by Lewis et al., (2016) for golfers >30 years of age, but for golfers <30 (mean = 25.6 ± 2.9) years of age, only the seated MB chest throw had a significant correlation with CHS. For junior golfers on a performance pathway (aged 15.1 ± 0.8 years of age) there were significant relationships reported between both the seated single arm and the standing rotational MB throws with CHS (Coughlan et al., 2020). A note of caution: an eight-week plyometric intervention noted significant improvements in a MB chest and rotational throw in both the intervention group and control. Therefore, it is likely that changes in throwing distance are partially due to learned effects (Bliss et al., 2015). MB throw testing provides S&C coaches with a useful field-based protocol to profile golfers of all ages, however, coaches must ensure a consistent technique is used with the same weight MB at pre- and post-testing sessions (3-4 kg is suggested). Additionally, familiarisation trials should be offered to the golfer before recording a measurement.

Conclusion

Establishing the needs and goals of each individual golfer is paramount to the effectiveness of any S&C intervention. In doing so, the S&C coach needs to understand the demands of the sport and the athlete to ensure an appropriate, systematic programme can be developed as part of a periodised plan. Adopting a holistic, multi-disciplinary approach to the needs analysis and subsequent interventions will allow the optimisation of training load to elicit functional adaptations to improve performance and reduce the risk of injury. In order to benchmark and assess the impact of prescribed S&C interventions it is important that time efficient and appropriate profiling protocols are utilised in the field. This chapter has recommended the use of various methods and encouraged the application of tests most appropriate to equipment accessibility and the golfer's needs. With the shift in culture towards S&C engagement within golf, research has demonstrated the importance of assessing vGRF (i.e., impulse) with a view to enhanced functional adaptations leading to greater drive performance measures. Where physical restrictions are impacting on the ball flight and swing characteristics, ROM testing may have a place, but it is important that these tests are used as part of an assessment and not relied on to predict why specific movements are occurring in the swing. Above all, the S&C coach implementing the tests should be aware of how to ensure reliability and validity and use

the data to adapt S&C programmes effectively rather than collect the data for no reason. Optimal functional adaptation will only occur through the systematic S&C programme when an exhaustive needs analysis process, reliable profiling tests, effective coach-athlete relationships, and monitoring of each golfer's availability and readiness to train and compete are in place and adapted, as appropriate, to meet the needs and goals of each individual.

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