

WATER-POLO PLAYER PHYSIOLOGY REPORT:

1. INTRODUCTION:

1.1 Physiological Demands

Water polo (WP) is a high-intensity, intermittent sport, involving short bursts of sprint swimming, changes of direction, technical-tactical decisions and short recovery periods (Barrenetxea-Garcia *et al.*, 2024). These short bursts are accompanied by periods of low intensity swimming or treading water (using an 'egg-beater kick') (Croteau, Felix *et al.*, 2021). International WP games consist of 4x7-minute periods of play separated by 2-minute intervals, the total duration of a game can range between ~55-70-minutes when factoring in overtime (Smith, 1998).

The metabolic profile of WP is predominantly aerobic (~50-60%), due to the high volume of total distance covered (~1500-2000m per match), however, explosive movements such as sprinting for the ball, jump-blocking and high-velocity throwing rely on the alactic (~30-35%) and lactic (10-15%) anaerobic systems (Botonis, Petros G., Toubekis and Platanou, 2018; Platanou, 2009). Successful performance depends on the ability to rise explosively out of the water for blocking or shooting, requiring exceptional leg strength and anaerobic power (Botonis *et al.*, 2018). It also depends on high-velocity throwing and the ability to stabilise against contact, thus demanding strong shoulder musculature, flexibility and robust trunk strength (Canossa *et al.*, 2020; Gardasevic, 2026). Rapid acceleration and change of direction is vital to maximise goal-scoring opportunities, with athletes needing high agility (Tucher *et al.*, 2014). Overall, WP is a highly multi-factorial sport requiring athletes to be proficient across a wide range of physiological qualities.

Additionally, the environment of aquatic sports can impose unique physiological effects, including reduced thermoregulatory efficiency, altered cardiovascular responses and increased hydrostatic pressure, all of which influence metabolic cost and recovery during matches (Torres-Ronda and del Alcázar, 2014; Fujimoto *et al.*, 2015; Pendergast *et al.*, 2015). WP players must continually generate high-propulsive force to overcome hydrodynamic resistance during swimming, rapid accelerations and vertical movements, placing higher demands on the aerobic and anaerobic system for sustained propulsion across repeated efforts (Ungerechts, 1992; Gatta, Cortesi and Zamparo, 2016).

1.2 Positional Specificity

The different positions in WP, including goalkeepers, centre-forwards, centre-defenders, wings and drivers, have specific physiological demands associated with their role (Kovačević *et al.*, 2025). The 'driver' is a perimeter player and the goal-shooter of the team, requiring high-level speed, strength and agility to push through the offence for goal-scoring opportunities, this differs majorly from the more static roles of the centre players who must have high strength and body mass to hold key pool positions (Kovačević *et al.*, 2025). Time-motion analysis of elite female matches revealed that perimeter players complete significantly more sprint swimming (2:09 vs 0:52mins) and high intensity bouts (~7s vs ~5s) than other players, necessitating superior anaerobic capacity, repeated sprint ability and explosiveness (D'Auria and Gabbett, 2008; Tan, Polglaze and Dawson, 2009).

According to Klikovac, Song and Uljević (2022) perimeter players typically exhibit lower body mass and skinfold totals than centre players, as a superior power-to-weight ratio allows increased speed.

1.3 Subject Overview and Lifestyle Factors

The subject of this report is a 20-year-old female water polo player (Height: 171cm; Mass: 73.8kg) competing at a national level in the driver position. Her current training programme includes 4 x 2.5-hour pool-sessions and 1 resistance-based gym session per week, alongside weekend matchplay.

This subjects training volume (~12-hours) and competition level aligns with a 'highly-trained' athlete according to McKay *et al.*, (2021). Alongside managing high-level training demands, the subject is in full-time university study and part-time employment. This may impact the subjects recovery and performance due to increased stressors, potentially widening the performance gap compared to full-time elite athletes. The aim of this report is to compare the subject's current physiological measures against a general population of female students ($n=65$) through z-scores and against elite Olympic data to identify specific performance gaps. Given the demands of the sport, the assessments chosen for this case study targeted the key determinants of WP performance, including aerobic capacity, anaerobic power and muscular strength.

2. METHODOLOGY

2.1 Ethical Considerations

The participant provided informed consent prior to participation and completed a physical activity readiness questionnaire (PAR-Q) to ensure they were safe to take part and exercise at maximal exertion. Testing was conducted over three non-consecutive days to reduce effects of residual fatigue and at the same time and place to reduce variance. A standardised RAMP warm up and cool-down was completed for each testing day, where appropriate, the best of three trials was recorded as the result.

2.2 Day 1: Muscular Strength, Power and Body Composition

Anthropometry:

Height was measured to the nearest 0.1cm using a Seca 213 stadiometer (Seca GmbH & Co. KG, Hamburg, Germany, a), body mass was recorded to the nearest 0.1kg using Seca 875 digital scales (Seca GmbH & Co. KG, Hamburg, Germany, b). Body composition was assessed by skinfold measurement at 8 sites (tricep, subscapular, bicep, iliac crest, supraspinale, abdominal, thigh, calf), this was completed by the clubs physiologist (ISAK qualified) using Harpenden callipers (Baty International (Bowers Group), Burgess Hill, West Sussex, UK) (Alcaraz *et al.*, 2011).

Strength and Power:

1RM Squat: Followed NSCA protocol. Single repetitions were performed at progressively heavier weights until failure, with 3-5 attempts to determine 1RM excluding warm-up lifts (Brown *et al.*, 2001).

Countermovement jump (CMJ): Jump height was measured using an FP8 2003 Force-platform (HUR Oy Kokkola, Finland). The participant performed 3 maximal jumps with hands on hips to isolate lower-body power (De Siati *et al.*, 2016).

Seated medicine ball throw (SMBT): Maximal chest pass with a 2kg ball from a 90° seated position with back flat against the wall to isolate upper-body power. The starting point for the throw was marked on the floor and distance thrown was measured in metres. 3 attempts were completed with 1-minute between each (Biggar and Larson, 2022).

Handgrip strength: Takei hand grip dynamometer (Takei Scientific Instruments Co., Ltd., Niigata, Japan) was held palm facing up, elbow at 90°, a maximal squeeze was held for 3-seconds with 3 attempts for both hands (Alcaraz *et al.*, 2011).

Flexibility: Reaching as far as possible with extended arms and extended knees over a sit-and-reach box (HaB International Ltd, UK) to measure hamstring and lower-back flexibility. The best of 3 trials was recorded (Ferguson, 2014).

2.3 Day 2: Anaerobic Power Assessment

Wingate Anaerobic Test (WanT): 30-second maximal effort Wingate test performed on a Monark Ergonomic 894E bike (Monark Exercise AB, Sweden). Resistance was set at 7.5% of participants body mass (Zupan *et al.*, 2009). The participant was instructed to pedal at maximum speed against the resistance for the full 30-seconds. Peak power (PP), mean power (MP) and power decline were recorded.

2.4 Day 3: Aerobic Capacity Assessment

Maximal Oxygen Uptake (VO₂ max): a cycle-based protocol using a Wattbike Pro (Wattbike Ltd, UK) was selected over treadmill running to more accurately replicate leg-action mechanics of the 'egg-beater kick' in WP.

Starting at 50-watts, a ramp test to exhaustion involved increasing wattage by 15-watts per minute until participant reached volitional exhaustion (McConnell *et al.*, 1997). 100L Douglas bags (Hans Rudolph Inc., Shawnee, KS, USA) were used to collect the final minute of expired air which was analysed using Servomex 5200 (Servomex Group Ltd, Crowborough, East Sussex, UK) and Harvard DGM1 meters (Harvard Apparatus, Holliston, MA, USA). HR was measured continuously via chest strap and a Polar heart-rate monitor (Polar Electro Oy, Finland).

2.5 Data Analysis

To compare the participant to a general student population, z-scores were calculated using the formula: $z = (x - \mu) / \sigma$. Where x is the participant's score, μ is the female student cohort mean and σ is the standard deviation (Andrade, 2021). Published normative data from

Klikovac, Song and Uljević (2022) and Marrin and Bampouras (2008) on professional international female WP players was used as elite benchmarks.

3. RESULTS

Table 1: Muscular Strength, Power and Anthropometry

Variable (Units)	Subject Score	Student Mean $\pm$ SD	Z-Score	Elite Perimeter Norm $\pm$ SD	Elite Source
ANTHROPOMETRY					
Height (cm)	171.0	164.4 $\pm$ 6.3	1.04	171 $\pm$ 10.8	Marrin and Bampouras (2008)
Body Mass (kg)	73.8	65.0 $\pm$ 12.2	0.72	66.3 $\pm$ 4.7	Marrin and Bampouras (2008)
Body Fat (%)	24.8	28.1 $\pm$ 8.4	-0.40	19.5 $\pm$ 3.8	Marrin and Bampouras (2008)
STRENGTH & POWER					
1RM Squat (kg)	75	————	————	104.4 $\pm$ 13.5	Klikovac, Song and Uljević (2022)
Handgrip Right Hand (kg)	39.7	41.2 $\pm$ 16.8	-0.09	41.7 $\pm$ 6.0	Klikovac, Song and Uljević (2022)
Handgrip Left Hand (kg)	38.2	41.2 $\pm$ 16.8	-0.18	41.1 $\pm$ 5.2	Klikovac, Song and Uljević (2022)
CMJ (cm)	41.0	32.2 $\pm$ 7.6	1.16	49.6 $\pm$ 6.5	Platanou (2005)
SMBT (cm)	301	195.7 $\pm$ 40.8	2.58	597 $\pm$ 90	Lockie <i>et al.</i> , (2023)
Sit-and-reach (cm)	30.6	23.2 $\pm$ 15.1	0.49	35.8 $\pm$ 7.0	Marrin and Bampouras (2008)

Anthropometry: The participant was within the elite norms for height (171 $\pm$ 10.8), although her body mass (73.8kg) and body fat percentage (24.8%) was moderately higher than the elite measurements (66.3 $\pm$ 4.7; 19.5 $\pm$ 3.8).

Student Data Comparison: The most significant statistical variance from the female student data was observed in the SMBT ($z = +2.58$), indicating superior upper body power.

Performance Gaps: A deficit in strength is evident in the 1RM Squat (75kg) which is 28.2% lower than the elite standard (104.4kg), additionally, while the participant's CMJ (41.0cm) was superior to students ($z = +1.16$), it was 8.6cm below the elite threshold.

Table 2: Aerobic and Anaerobic profile

Variable (Units)	Subject Score	Student Mean $\pm$ SD	Z-Score	Elite Perimeter Norm $\pm$ SD	Elite Source
AEROBIC (VO2 Max)					
Peak Oxygen Uptake (mL/kg/min)	45.4	40.0 $\pm$ 11.0	0.49	51.4 $\pm$ 5.9	Marrin and Bampouras (2008)
Peak Heart Rate (bpm)	195	————	————	193 $\pm$ 3.0	Marrin and Bampouras (2008)
ANAEROBIC (WanT)					
Peak Power (W)	768.3	613.0 $\pm$ 125.5	1.24	608 $\pm$ 40.0	Marrin and Bampouras (2008)
Mean Power (W)	463.1	421.0 $\pm$ 79.7	0.53	458.2 $\pm$ 30.3	Marrin and Bampouras (2008)
Power Decline (%)	58.0	55.6 $\pm$ 10.8	0.22	42.8 $\pm$ 10.9	Marrin and Bampouras (2008)

Anaerobic Capacity: The participant's Wingate PP (768.3W) was significantly higher than the general student population ($z = 1.24$). This score exceeded the elite norm (608 $\pm$ 40W) suggesting the participant has elite-level anaerobic power.

Fatigue Resistance: The participant presented high-power decline (58%) which is 15.2% greater than the elite norm (42.8%). This indicates a weakness in maintaining high-intensity outputs over a prolonged duration.

Aerobic Capacity: The subjects relative VO2 max (45ml/kg/min) is above the student average ($z = +0.49$) and sits within 6ml/kg/min of the elite standard.

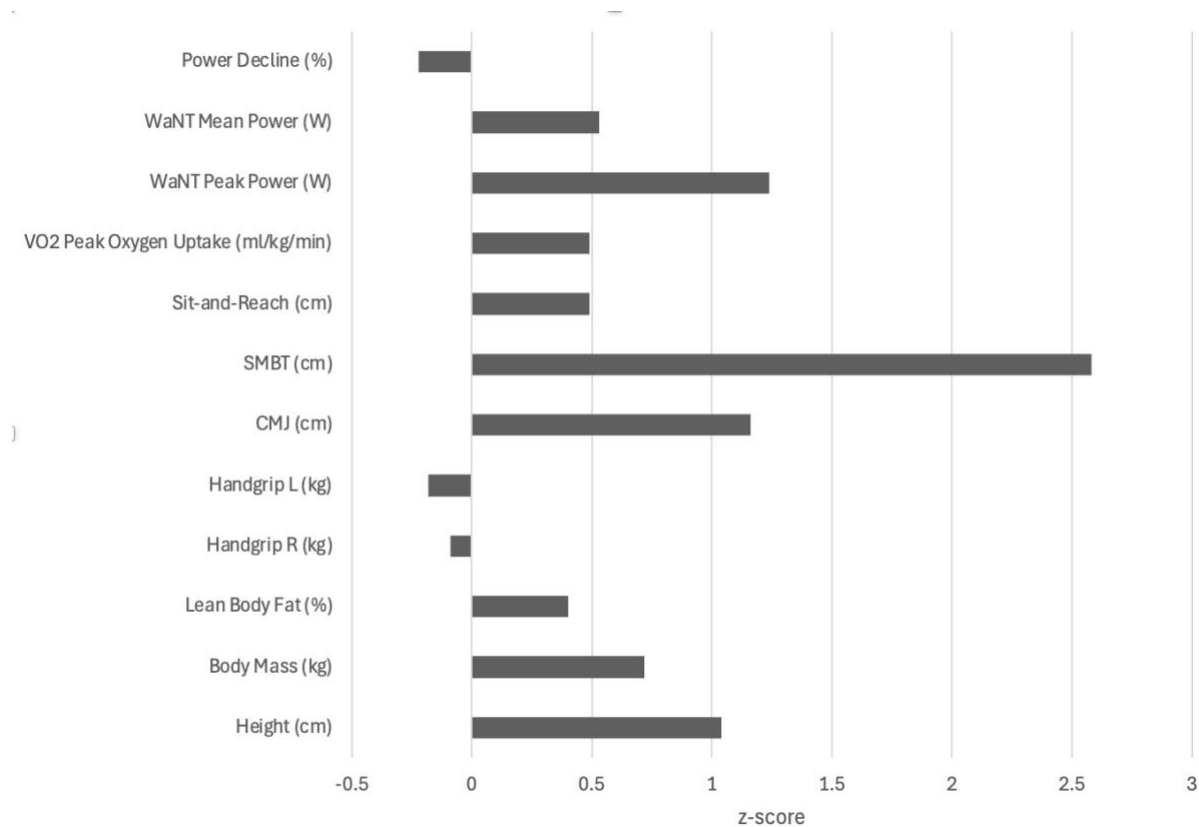


FIGURE 1: Z-score profile of a female national-level WP driver compared to a female student cohort ($n=65$). Bars to the right represent superior performance relative to the mean.

The z-score profile highlights exceptional functional power, specifically in the SMBT ($z= 2.58$), Wingate PP ($z= 1.24$) and CMJ ($z = 1.16$). Conversely, this highlights handgrip strength ($z= -0.18$) and power decline ($z= 0.22$) as inferior to the general student cohort, suggesting anaerobic endurance and distal strength as improvement areas.

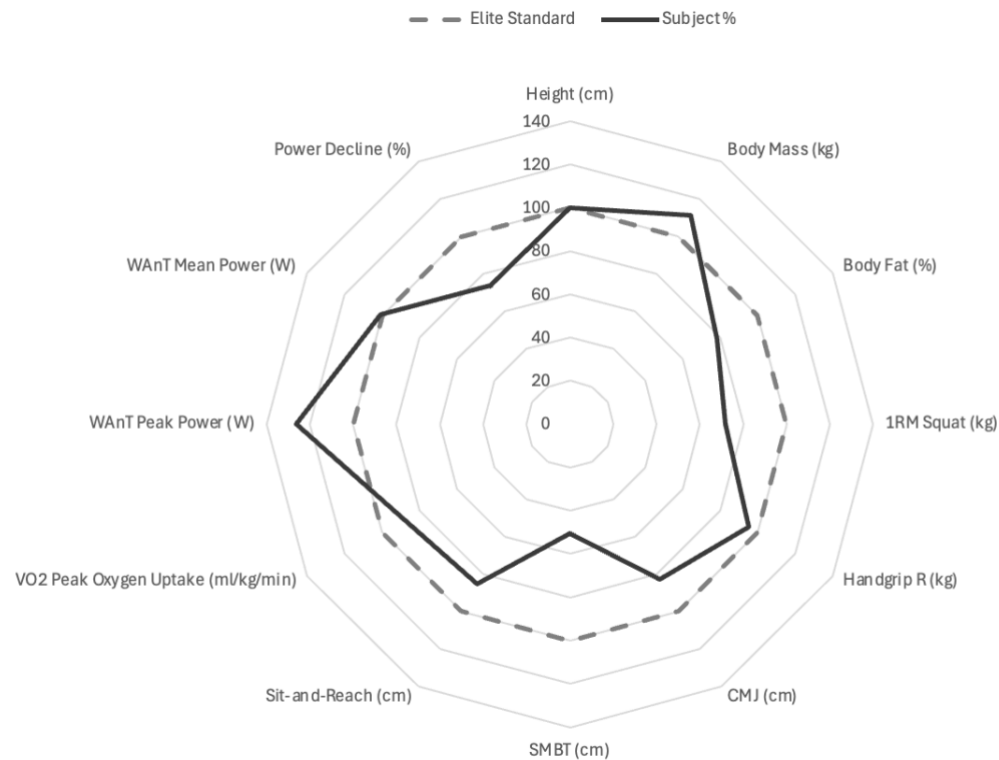


Figure 2: Comparison of participant performance against elite female player benchmarks (100%). Scores outside of 100% perimeter represent elite-level measures.

The radar profile shows that the participant demonstrates elite-level anaerobic explosive capacity, with Wingate PP exceeding the elite benchmark by 26.3%. However, this does not translate into upper-body power (SMBT) or absolute lower-body strength (1RM squat), where significant performance gaps exist (50.4%; 71.8%). Power decline and BF % are both highlighted weakness areas, with both sitting 20-30% away from elite standards.

4. DISCUSSION

4.1 Positional Demands and Anthropometry

The participant's height aligns closely with elite female WP norms (171 ± 10.8 cm) providing a competitive advantage for blocking, shooting and maintaining speed during perimeter play (Marrin and Bampouras, 2008; Gardasevic, 2026). Her body fat percentage (24.8%) is higher than the elite value of $\sim 19.5\%$, yet remains within the upper boundary of what is considered 'optimal' for female athletes (20-24%) (Baranauskas *et al.*, 2023). Although slightly higher

amounts of adipose tissue may assist buoyancy during low intensity recovery periods, a reduction towards the 'lean' 15-19% range would likely enhance hydrodynamic efficiency by decreasing drag and improving propulsion (Smith, 1998). This is particularly important for a driver whose role depends on repeated accelerations and high-speed movement (Lowensteyn, Signorile and Giltz, 1994). Increasing lean muscle mass alongside a modest reduction in body fat would therefore support positional demands and overall performance.

4.2 Power Strength Paradox

A notable finding is the discrepancy between the participant's exceptional anaerobic power (Wingate PP: $z = +1.24$; 126% of elite) and her comparatively low scores in the 1RM squat (71.8% of elite) and SMBT (50.4% of elite). This profile indicates that while this participant can produce very high immediate power, her underlying maximal force-production capacity is limited, reducing her ability to express this power in tasks requiring movements of heavy loads or high-throwing forces (Suchomel, Nimphius and Stone, 2016).

In WP, the eggbeater kick and vertical elevation rely on repeatedly generating force against water resistance (Croteau et al., 2024). Without a higher maximal strength ceiling (such as elite players' 104kg 1RM squat), the athlete may not be able to fully convert her anaerobic power into effective propulsion for height out of the water in shooting and blocking (Yang *et al.*, 2025). Similarly, sub-optimal upper-body strength may restrict her ability to produce the high velocities required for long-range or under-pressure shooting (Arboix-Alió *et al.*, 2024; Ferragut *et al.*, 2011). Bloomfield *et al.*, (1990) found upper-body strength training was associated with significant improvements in throwing velocity of male elite WP players, however, there is limited research into specific female WP player throwing-velocities (Tan, Polglaze and Dawson, 2009). Overall, these findings suggest that targeting improvements in upper and lower-body maximal strength would enhance her ability to translate her existing anaerobic power into sport-specific performance (Sporis, Krakan and Fiorentini, 2011).

4.3 Metabolic Conditioning and Fatigue Index

While the participants VO2 max (45.4 ml/kg/min) represents a clear strength relative to female students, her 58% power decline across the Wingate test is a notable limitation. Elite female WP players typically maintain declines of ~42%, reflecting superior anaerobic capacity and fatigue resistance (Marrin and Bampouras, 2008). WP is characterised by repeated high-

intensity sprints separated by brief periods of low-intensity treading water or positional movement, placing heavy demands on the ability to recover quickly between bouts (Mujika *et al.*, 2025).

A high power decline indicates that while the participant can produce strong initial efforts, her ability to sustain high-intensity performance across a ~60-minute bout might be compromised. This pattern suggests limited tolerance to lactic acid accumulation and reduced buffering capacity, impairing her ability to clear metabolites (H⁺ ions, lactate) during short recovery intervals (Huang *et al.*, 2025; Faghy, Lomax and Brown, 2018). As a result, repeated sprint performance, shooting velocity and late-game explosiveness may deteriorate more rapidly than in elite player counterparts (Edg *et al.*, 2006; Cao *et al.*, 2025). Improving this participant's anaerobic tolerance and buffering capacity should be prioritised to help sustain high-intensity performance throughout the full match duration.

4.4 Flexibility, Mobility and Injury-Risk

The participants sit-and-reach score (30.6cm), while higher than general student measurements (23.2±15.1), was lower than elite norms (35.8±7cm), indicating limited hamstring and lower-back flexibility. While flexibility is not the primary determinant of performance in WP, insufficient mobility can lead to restricted stroke efficiency, sub-optimal body position during defensive manoeuvres and increase the metabolic cost of movements (Dwivedi, 2025; Asal and Özünlü Pekyavas, 2026). Specifically for a driver, reduced trunk and hip mobility may limit rotational range during shooting and impair the ability to perform wrestling movements when under contact (Ramos *et al.*, 2020). Furthermore, restricted flexibility is associated with increased injury risk, particularly in sports requiring repeated overhead actions and rapid changes in direction. For example, up to 80% of WP players present with shoulder and rotator cuff pain due to repetitive overuse and reduced stability and mobility (McMaster, Long and Caiozzo, 1991; Borsa, Laudner and Sauers, 2008; Webster, Morris and Galna, 2009). Improving hip, trunk and shoulder flexibility would support performance efficiency and reduce long-term injury risk (López-Laval *et al.*, 2022).

4.5 Evidence-based Training Recommendations

Area of Focus	Recommendation	Rationale for WP
Maximal Strength	Heavy Resistance Training: 3-5 reps, >85% 1RM (back squat, bench press, hip-lift, overhead press) (Ramos Veliz <i>et al.</i> , 2014; Malliaros <i>et al.</i> , 2025)	Increasing maximal force production enables the participant to convert existing anaerobic power into greater vertical elevation, stronger wrestling positions and higher-velocity shooting (Sporis, 2011; Yang <i>et al.</i> , 2025)
Functional Power	Ballistic & Sport Specific Power Training: Medicine ball rotational throws, overhead slams, water-based resistance egg-beater kick (Bouagina <i>et al.</i> , 2022; Malliaros <i>et al.</i> , 2025; Sadek, 2025)	Enhances rate of force development and improves the participant's transfer of strength into explosive movements such as shooting, blocking and rapid accelerations (Sáez de Villarreal <i>et al.</i> , 2015)
Anaerobic Endurance	Repeated Sprint Ability Training: Short distance maximal effort sprints with limited rest (10x25m, 20s rest) (Meckel <i>et al.</i> , 2013; Dalamitros <i>et al.</i> , 2021)	Targets the participant's sub-optimal power decline by improving glycolytic tolerance and buffering capacity, supporting sustained high-intensity efforts across full match duration (Huang <i>et al.</i> , 2025; Miguel-Ortega <i>et al.</i> , 2025)
Mobility & Injury Prevention	Targeted Mobility Work: 10-15mins per session (areas of focus: hip flexors, shoulder mobility and stability, thoracic rotation) (López-Laval <i>et al.</i> , 2022; Croteau, 2021)	Improved mobility supports efficient stroke and technique, greater trunk rotation for shooting and reduces injury risk with repeated overhead actions (Borsa, Laudner and Sauers, 2008; Sioutis <i>et al.</i>)
Body Composition	Hypertrophy & Nutrition: Resistance training, increased protein and energy balance monitoring (Morton <i>et al.</i> , 2018; Morton, McGlory and Phillips, 2015)	Increasing lean muscle mass while reducing body fat improves power-to-weight ratio, reducing drag and enhancing propulsion (Narita <i>et al.</i> , 2025)

5. CONCLUSION

Overall, the participant presents a strong physiological foundation for the driver position in WP, with above average aerobic capacity and exceptional lower-limb anaerobic power. However, key deficits were identified in maximal strength, upper-body force production, repeated sprint tolerance and body composition, all of which negatively impact her ability to sustain high-intensity efforts and effective recovery across a full match. Addressing these gaps through targeted strength and mobility development, anaerobic training and improvements in lean mass would enhance her overall performance in training and competition.

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