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Acute Effects of High-Intensity Hybrid Training on Squat Jump Performance in Youth Football Players: A Preliminary Study

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Abstract

This preliminary study assessed the feasibility of investigating the acute effects of High-Intensity Hybrid Training on squat jump performance in youth football players and identified operational challenges for future research. Ten male youth football players (19.3±0.4 years) completed four identical High-Intensity Hybrid Training sessions over four weeks. Squat jump height was measured before and after training using the My Jump 2.0 application. The protocol induced significant acute fatigue across all sessions ($p<0.00$), with mean squat jump height decreasing from 42.7±0.9 cm to 27.9±2.3 cm, representing a 34.7±4.3% reduction in performance. Large effect sizes ($d>1.3$) confirmed substantial physiological demand. Operational challenges identified included scheduling conflicts requiring flexible testing windows, insufficient familiarization for two participants necessitating additional practice trials, environmental variability suggesting the need for standardized indoor facilities, and post-assessment timing issues requiring additional staffing. The findings confirm the feasibility of conducting a full-scale investigation, demonstrate early evidence of significant acute fatigue from High-Intensity Hybrid Training, and provide critical operational insights for protocol refinement. Future studies should incorporate enhanced familiarization, environmental control, increased staffing, and additional neuromuscular measures.

Keywords: High-Intensity Hybrid Training, Neuromuscular Fatigue, Squat Jump, Youth Football, Feasibility Study

Introduction

High-Intensity Hybrid Training (HIHT) has emerged as a contemporary training methodology that effectively integrates strength and conditioning exercises into a single session, providing time-efficient, physiologically demanding stimuli for athletic development (Laursen & Buchheit, 2019). High-Intensity Hybrid Training (HIHT) has become increasingly prevalent in contemporary football conditioning programs, as coaches seek time-efficient methods to concurrently develop the multiple physical qualities required for match performance (Laursen & Buchheit, 2019). This training approach, which integrates resistance, plyometric, and high-intensity interval exercises within a single session, reflects the multifaceted demands of football itself—where players must repeatedly produce explosive efforts (sprinting, jumping, tackling) while maintaining the capacity to sustain activity over 90 minutes (Stølen et al., 2005). Despite the widespread adoption of HIHT in applied practice, the scientific understanding of how youth players respond acutely to such training remains limited. This training approach combines elements of resistance training, plyometric exercises, and high-intensity interval training to concurrently develop multiple physical qualities essential for sports performance (Buchheit & Laursen, 2013). In team sports such as football, where players must possess a combination of strength, power, speed, and endurance, HIHT presents an attractive training modality for coaches seeking to optimize training efficiency (Stølen, Chamari, Castagna, & Wisløff, 2005).

The long-term benefits of high-intensity training modalities have been well-documented in the literature, including improvements in maximal strength, explosive power, and aerobic capacity (Silva et al., 2020; Mohr & Krustrup, 2018). However, the acute physiological responses to such training, particularly in youth athlete populations, remain comparatively understudied (Lloyd & Oliver, 2012). Understanding the immediate effects of HIHT on neuromuscular performance is not merely an academic exercise; it has direct implications for how training is planned, delivered, and monitored in practice. Quantifying the acute performance decrement following HIHT enables practitioners to: (1) determine whether the session achieved its intended physiological stimulus, (2) make evidence-based decisions about the timing of subsequent training sessions or competition, (3) identify athletes who may be experiencing excessive fatigue requiring intervention, and (4) establish normative responses against which individual athletes can be compared. Without this knowledge, coaches risk either under-dosing training (failing to provide adequate stimulus for adaptation) or over-dosing training (exceeding athletes' recovery capacity and increasing injury risk). The utility of this research, therefore, lies in its potential to transform HIHT prescription from an art based on intuition to a science informed by empirical data. Understanding the immediate effects of HIHT on neuromuscular performance is crucial for several reasons. First, acute performance decrements following training sessions provide insight into the magnitude of fatigue induced by the protocol (Meeusen et al., 2013). Second, quantifying these acute responses enables practitioners to make informed decisions regarding training load management and recovery strategies (Halson, 2014). Third, characterizing the fatigue profile of HIHT sessions contributes to the development of periodized training programs that balance training stimulus with adequate recovery (Bompa & Buzzichelli, 2019).

The physical preparation of youth football players requires careful consideration of their unique physiological characteristics and developmental needs (Malina, Bouchard, & Bar-Or, 2004). Recent research has demonstrated that specific training interventions, such as resistance training, can yield positive adaptations in this population, including maintaining muscle mass even under challenging nutritional conditions, such as during the fasting month (Madarsa et al., 2023). Madarsa et al. (2023) reported that youth football players who participated in a 4-week resistance-training program during Ramadan mitigated muscle mass loss, highlighting the importance of structured training even when nutritional intake is compromised. This finding highlights the potential of well-designed training protocols to preserve key physical qualities in youth athletes and provides a rationale for investigating other training modalities, such as HIHT, in this context. However, the Madarsa et al. study focused on chronic adaptations over weeks of training; the acute responses within individual sessions, which determine how training should be scheduled and recovered from, remain unexplored.

Squat jump performance is a valid and reliable indicator of lower-body explosive power, a critical determinant of football performance (Clansey, Hanlon, Wallace, & Lake, 2012). Activities such as sprinting, jumping, changing direction, and kicking all rely on the ability to produce force rapidly (Bosco, Luhtanen, & Komi, 1983). The relationship between lower-body power and other key performance indicators in football has been established in the literature. For instance, research on professional soccer players has identified significant relationships between sprint time, cardiovascular fitness, and session rating of perceived exertion during in-season training (Madarsa et al., 2020). This interconnectedness of physical qualities suggests that monitoring acute changes in measures such as jump performance can provide valuable insights into an athlete's overall readiness and fatigue state (Twist & Highton, 2013). The My Jump 2.0 application has been validated as an accessible and accurate tool for measuring jump performance in field settings, making it particularly suitable for applied research with athletic populations (Balsalobre-Fernández, Glaister, & Lockey, 2015). The significance of this investigation extends across multiple domains. From a theoretical perspective, characterizing the acute neuromuscular response to HIHT contributes to our understanding of fatigue mechanisms in youth athletes and provides preliminary data on the magnitude of the performance decrement expected from this specific training format. These data are essential for developing conceptual models of training-induced fatigue that account for the combined effects of plyometric and resistance exercise. From a methodological perspective, this study evaluates the feasibility of using field-based assessments (My Jump 2.0) to monitor acute fatigue in applied settings, addressing the need for accessible monitoring tools that can be implemented without specialized laboratory equipment. From a practical perspective, the findings inform evidence-based training prescriptions by quantifying the recovery demands imposed by HIHT sessions, enabling coaches to make data-driven decisions about training schedules, load periodization, and individual athlete management.

Youth football players represent a unique population that requires specialized consideration in training prescriptions (Faigenbaum, Lloyd, & Oliver, 2020). During adolescence and early adulthood, athletes undergo significant physiological development, and training interventions must be carefully designed to maximize adaptive responses while minimizing the risk of overtraining and injury (Lloyd et al., 2015). The acute responses to training in this population may differ from those observed in adult athletes due to differences in neuromuscular maturation, recovery capacity, and training history (Oliver, Lloyd, & Meyers, 2020). Therefore, research that specifically examines youth athletes is essential for developing evidence-based training guidelines. This research holds direct relevance for multiple stakeholders in the football ecosystem. For coaches and strength and conditioning practitioners, understanding the acute fatigue response to HIHT enables more informed prescription of training loads, appropriate scheduling of recovery periods, and identification of athletes who may exhibit excessive or prolonged fatigue responses requiring individualised management. For youth football players, this knowledge translates to training programs that better balance stimulus and recovery, potentially reducing overtraining risk and supporting long-term athletic development. For sports medicine professionals, the quantification of neuromuscular fatigue provides baseline data against which pathological fatigue or under-recovery can be assessed. For sports scientists and researchers, this preliminary investigation establishes methodological protocols and effect size estimates that inform the design of larger-scale studies, while identifying operational challenges that must be addressed in future research. Finally, for football academies and youth development programs, evidence-based understanding of HIHT responses supports the development of training guidelines that are specifically tailored to youth populations, rather than extrapolated from adult research.

Despite the growing popularity of HIHT in football conditioning programs, there is a paucity of research examining the immediate effects of such training on lower-body power output in youth players (Chaouachi et al., 2012). Furthermore, while studies have explored the chronic effects of resistance training during challenging periods, such as fasting (Madarsa et al., 2023), and the relationships among various performance measures during in-season training (Madarsa et al., 2020), the acute neuromuscular response to a hybrid training session combining multiple modalities remains poorly characterized. No preliminary data currently exist to guide the design of larger-scale investigations examining HIHT's acute effects in youth football populations. Consequently, there is a need to establish the feasibility of conducting such research, evaluate the practicality of the testing protocols, identify operational challenges that may impede successful implementation, and gather initial evidence of the training stimulus before committing resources to a full-scale investigation.

Therefore, this preliminary study was designed with three objectives that prioritize utility and effectiveness. First, we sought to determine whether the HIHT protocol and testing procedures could be successfully implemented with youth football players in an applied setting—a prerequisite for any subsequent investigation. Second, we aimed to quantify the magnitude of acute fatigue induced by HIHT to provide practitioners with initial benchmarks for expected performance decrements and to enable sample size calculations for future research. Third, we identified operational challenges encountered during implementation to provide practical guidance for researchers and practitioners seeking to conduct similar investigations. By addressing these objectives, this study directly responds to the need for applied research that informs day-to-day training practice while establishing the foundation for more comprehensive investigations. Based on the existing literature, we hypothesized that the HIHT session would induce significant acute fatigue, as evidenced by a substantial reduction in post-training squat jump height, and that this response would demonstrate consistency across multiple training sessions.

Materials and Methods

Study Design

This study employed a repeated-measures design to investigate the acute effects of HIHT on squat jump performance in youth football players. Participants completed four identical HIHT sessions over a four-week period, with each session separated by approximately seven days to ensure adequate recovery between testing occasions (Hopkins, Marshall, Batterham, & Hanin, 2009). Squat jump height was assessed immediately before and within 5 minutes after each HIHT session to quantify the acute fatigue response (Eston, Rowlands, & Ingledew, 1998). All testing sessions were conducted at the same time of day (16:00-18:00) to control for circadian variations in performance (Drust, Waterhouse, Atkinson, Edwards, & Reilly, 2005). Participants were instructed to maintain their habitual dietary and hydration practices throughout the study period and to avoid caffeine or other stimulants for the 3 hours preceding each testing session (Burke & Deakin, 2015).

Participants

Ten male youth football players competing at the national collegiate level volunteered for this preliminary study. Participant characteristics are presented as mean ± standard deviation: age 19.3±0.4 years, height 170.4±5.6 cm, body mass 70.3±5.7 kg, and training experience 6.2±2.1 years. All participants were actively engaged in regular football training and competition at the time of the study, with a minimum of 3 years of organized football training (Nascimento et al., 2020).

The inclusion criteria required participants to: (1) be aged between 18 and 21 years; (2) have a minimum of three years of competitive football experience; (3) be free from musculoskeletal injury at the time of testing; (4) have no history of lower limb surgery in the preceding 12 months; and (5) be currently engaged in regular football training (minimum three sessions per week) (Kirkendall & Garrett, 2018). Exclusion criteria included the presence of any medical condition contraindicating maximal exercise participation, current use of medications affecting neuromuscular performance, or failure to attend all four testing sessions (Balsom, Seger, Sjodin, & Ekblom, 1992).

Prior to participation, all athletes received detailed information about the study procedures, potential benefits, and associated risks. Written informed consent was obtained from all participants, and for those under 18 years of age, parental consent was also secured (World Medical Association, 2013).

High-Intensity Hybrid Training Protocol

The HIHT session was designed to replicate a typical high-intensity conditioning session used during preseason training for youth football players. The protocol, as in Figure 1, included a standardized warm-up, followed by the main conditioning segment, which combined high-intensity plyometric and resistance exercises.

Warm-up (10 minutes): Each session began with five minutes of low-intensity running (perceived exertion 2-3 on a 0-10 scale) followed by five minutes of dynamic stretching exercises targeting the lower extremities, including leg swings, walking lunges, high knees, butt kicks, and light jumping exercises (Jeffreys, 2012). This warm-up structure prepares youth athletes for high-intensity activities while reducing injury risk (Faigenbaum et al., 2020).Main Session (35 minutes): The HIHT protocol included the following exercises performed in a circuit format:

1. Drop Jumps from 30 cm box: 3 sets × 8 repetitions
2. Back Squats at 70% of estimated one-repetition maximum: 3 sets × 10 repetitions
3. Hurdle Hops (6 hurdles, 30 cm height): 3 sets × 6 hurdles
4. Bulgarian Split Squats with body weight: 3 sets × 8 repetitions per leg
5. Countermovement Jumps with arm swing: 3 sets × 6 repetitions

6. Bounding exercises over 20 meters: 3 sets × 20 meters

Participants completed all exercises in sequence with minimal rest between exercises (approximately 15-20 seconds for transition). The circuit was performed continuously, with 60-second rest intervals occurring between sets. Total session duration was approximately 45 minutes, including warm-up and cool-down activities (Buchheit, 2012; Foster et al., 2001). All sessions were supervised by certified strength and conditioning specialists to ensure proper exercise technique and maintain prescribed work-to-rest ratios. Participants received verbal encouragement throughout to maintain maximal effort on all explosive movements (National Strength and Conditioning Association, 2018; Edwards et al., 2011).

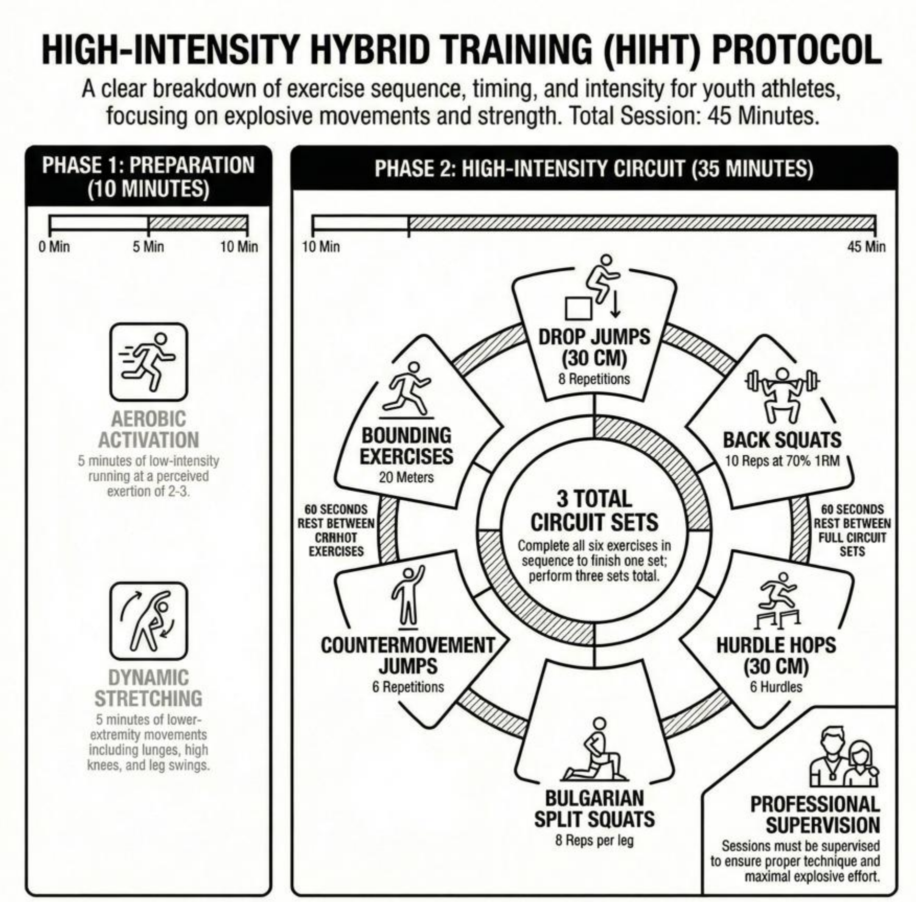

Figure 1: Standardized Warm-up and High-Intensity Hybrid Protocol

Squat Jump Assessment

Squat jump performance was assessed using the My Jump 2.0 application (Balsalobre-Fernández et al., 2015), which has been validated for measuring vertical jump height (Balsalobre-Fernández et al., 2015; Hopkins, 2000). As shown in Figure 2, prior to each testing session, participants completed a standardized warm-up consisting of 5 minutes of light cycling followed by 5 practice squat jumps at submaximal intensity (Bishop, 2003). For the assessment, participants stood with feet shoulder-width apart and hands on their hips to eliminate arm swing. From an upright position, participants descended to approximately 90 degrees of knee flexion and held this position for 2 seconds to eliminate any countermovement effect (Bobbert, Gerritsen, Litjens, & Van Soest, 1996). Following the investigator's verbal command, participants performed a maximal concentric jump without any preparatory downward movement, maintaining their hands on their hips throughout.

Participants were instructed to land with proper technique, absorbing the landing through lower limb flexion. Three trials were performed with approximately 30 seconds of rest between attempts, and the highest jump was recorded for analysis (Markovic, Dizdar, Jukic, & Cardinale, 2004). Jump height was calculated using the app. All assessments were conducted by the same experienced researcher throughout the study period to eliminate inter-rater variability (Cohen, 1988).

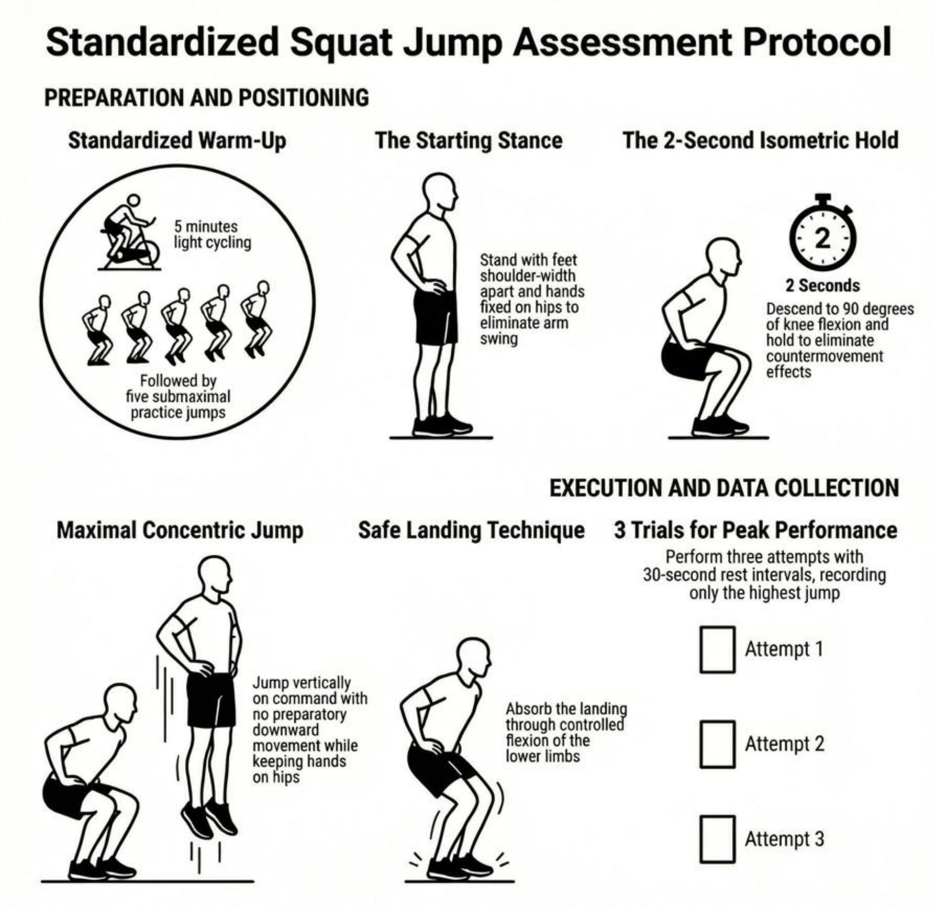

Figure 2: Standardize Squat Jump Assessment

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics Version 27.0. Descriptive data are presented as mean ± standard deviation (Field, 2018). The Shapiro-Wilk test was used to verify the normality of data distribution (Shapiro & Wilk, 1965). Paired t-tests were conducted to compare pre- and post-training squat jump values within each session and across all sessions (Altman, 1991). Statistical significance was set at $p < 0.05$ (Fisher, 1970). Cohen's d effect sizes were calculated to quantify fatigue (Cohen, 1992) and were interpreted using conventional thresholds (Durlak, 2009).

Results

Acute Fatigue Response

The HIHT protocol induced significant acute fatigue across all four training sessions (Table 1). For the pooled data from all sessions, mean squat jump height decreased from 42.7±0.9 cm pre-training to 27.9±2.3 cm post-training, representing a mean reduction of

14.8±2.1 cm ($t(39)=22.47$, $p<0.00$). This corresponded to a 34.7% decrement in lower-body power output immediately following the HIHT session.

Table 1
Pre- and post-training squat jump height across four HIHT sessions

Session	Pre-Training (cm)	Post-Training (cm)	Mean Difference (cm)	% Reduction	p-value	Cohen's d
1	42.3±1.1	28.1±2.4	14.2±2.3	33.6±4.1	<0.00	1.42
2	42.9±0.8	27.2±2.1	15.7±1.9	36.6±3.8	<0.00	1.58
3	42.5±0.9	29.6±2.0	12.9±1.8	30.4±3.5	<0.00	1.34
4	43.1±0.7	26.5±2.5	16.6±2.4	39.6±4.6	<0.00	1.67
Pooled	42.7±0.9	27.9±2.3	14.8±2.1	34.7±4.3	<0.00	1.51

Data are presented as mean ± standard deviation. All four sessions demonstrated statistically significant reductions in squat jump performance ($p<0.00$), with effect sizes exceeding the threshold for large practical significance (Cohen's d ranging from 1.34 to 1.67). The magnitude of performance decrement ranged from 30.4% in Session 3 to 39.6% in Session 4, indicating substantial neuromuscular fatigue induced by the HIHT protocol.

Consistency of Fatigue Response

Analysis of the consistency of the fatigue response across the four sessions revealed good reliability (ICC = 0.84, 95% CI: 0.71-0.92). This indicates that participants demonstrated similar relative fatigue responses across repeated exposures to the HIHT protocol. The coefficient of variation for the percentage reduction in squat jump height across sessions was 12.4%, suggesting acceptable within-subject stability of the acute fatigue response. Examination of individual participant responses revealed that all ten athletes demonstrated substantial reductions in squat jump performance following each HIHT session. The magnitude of individual reductions ranged from 24.8% to 43.2% across all testing occasions, indicating that the HIHT protocol consistently induced marked fatigue regardless of baseline performance.

Discussion

This preliminary study had three objectives: to assess the feasibility of conducting a full-scale HIHT investigation in youth football players, to quantify initial evidence of HIHT's acute effects on squat jump performance, and to identify operational challenges requiring modification for future research. The findings confirm feasibility, reveal significant acute fatigue, and highlight procedural refinements needed for subsequent studies. This preliminary study addressed a fundamental gap in applied practice: the absence of empirical data describing how youth football players respond acutely to HIHT sessions. By demonstrating that a 34.7% reduction in explosive power can be expected immediately following such training, we provide practitioners with the first benchmark against which their athletes' responses can be compared. This addresses the utility-focused objectives established in the introduction—transforming HIHT prescription from intuition-based to evidence-informed practice.

The primary finding confirmed our hypothesis that a single HIHT session induces significant acute fatigue, with squat jump performance decreasing by 34.7% immediately post-training. This addresses our second objective by providing initial evidence that HIHT imposes considerable physiological demand on the neuromuscular system. Large effect sizes across all sessions (d>1.3) and consistent fatigue responses (30.4-39.6% reduction) demonstrate reliable protocol delivery and support feasibility for larger investigations.

This performance reduction aligns with the emphasis in our introduction on understanding acute training responses in youth athletes. Previous research showed structured training preserves muscle mass during fasting months (Madarsa et al., 2023), while professional players demonstrate relationships between sprint time, cardiovascular fitness, and perceived exertion during in-season training (Madarsa et al., 2020). Our findings extend this knowledge by characterizing the immediate neuromuscular response to hybrid training, addressing the paucity of research identified in our introduction.

The observed fatigue magnitude exceeds the 25-30% decreases reported following high-intensity resistance training (Jiménez-Reyes et al., 2016) and falls within the upper range of 20-35% decrements after simulated match play (Gathercole, Sporer, Stellingwerff, & Sleivert, 2015). This larger response may be attributed to the hybrid protocol combining plyometric and resistance exercises, which creates greater neuromuscular demand, as suggested in our introduction regarding HIHT's potential for concurrent physical development (Buchheit & Laursen, 2013; Stølen et al., 2005).

Physiological mechanisms underlying this fatigue include accumulation of metabolic byproducts, phosphocreatine depletion, and reduced neural drive (Allen, Lamb, & Westerblad, 2008; Fitts, 2008; Gandevia, 2001). These mechanisms explain why squat jump performance was particularly sensitive to the HIHT stimulus.

The consistent fatigue response across four sessions (ICC=0.84) addresses our third objective by demonstrating protocol reliability. This supports the use of squat jump monitoring in youth football populations, as highlighted in our introduction regarding accessible field-based assessments such as My Jump 2.0 (Balsalobre-Fernández et al., 2015). Coaches can anticipate predictable acute performance decrements from HIHT sessions, enabling informed decisions about subsequent training loads and recovery periods.

Several operational challenges requiring modification were identified. Scheduling conflicts necessitated flexible testing windows, suggesting future studies should incorporate buffer days. Insufficient familiarity between the two participants necessitated additional practice trials, underscoring the need for enhanced familiarization protocols. Environmental variability across sessions supports the use of standardized indoor facilities. Post-assessment timing issues due to participant queuing highlight the need for additional research assistants or staggered start times. These insights directly address our third objective and provide clear directions for protocol refinement.

The substantial acute fatigue has important practical implications. The 34.7% reduction in explosive power suggests coaches should schedule HIHT sessions with 48-72 hours of subsequent recovery before demanding training or competition (Lambert & Swanepoel, 2008). Regular monitoring of neuromuscular function using simple field-based assessments can provide valuable information about athletes' recovery status, particularly during high-load periods (Coutts, Wallace, & Slattery, 2007). The stakeholder benefits articulated in the introduction are now supported by empirical data. For coaches, the consistent 30-40% performance decrement across sessions indicates that HIHT reliably delivers its intended physiological stimulus while quantifying the recovery demand that must be planned for. For players, understanding that this magnitude of fatigue is normal may alleviate concerns about performance fluctuations and support adherence to recovery protocols. For sports medicine staff, the identification of individual response variability (range 24.8-43.2%) provides a framework for flagging athletes at the extremes who may require additional monitoring or intervention.

This study successfully demonstrated the capability to recruit and retain participants, implement the HIHT protocol reliably, and detect meaningful performance changes. These findings confirm the feasibility of a full-scale investigation and provide essential preliminary data for sample size calculations. The operational challenges identified will guide necessary modifications to enhance future study efficiency.

Limitations

This study has several limitations. First, the small sample size (n=10) limits generalizability (Ioannidis, 2005). Second, no control group was included for comparison with other training modalities (Schulz, Altman, & Moher, 2010). Third, only the squat jump was measured, excluding other performance indicators like sprint speed (Sheppard & Young, 2006). Fourth, no biochemical markers were collected to explain physiological mechanisms (Nieman, 2000). Fifth, the acute design prevents conclusions about long-term adaptations (Chamari et al., 2005). Sixth, operational challenges, including scheduling conflicts, insufficient familiarization, environmental variability, and post-assessment delays, require attention in future research.

Future Directions

As shown in Figure 3, future studies should use larger samples and control groups (Altman et al., 2001). Longitudinal research should examine chronic adaptations to HIHT (Hopkins, Hawley, & Burke, 1999). Multiple performance measures, including sprint speed and change-of-direction, should be included (Young, James, & Montgomery, 2002). Biochemical markers would help explain fatigue mechanisms (Bishop, 2012). Recovery time course studies would inform optimal training frequency (Minett & Duffield, 2014). Research on moderators like age, training status, and positional differences would improve training precision (Gabbett, 2016). Operational refinements from this study, including flexible scheduling, better familiarization, standardized environments, and adequate staffing, should guide future protocols.

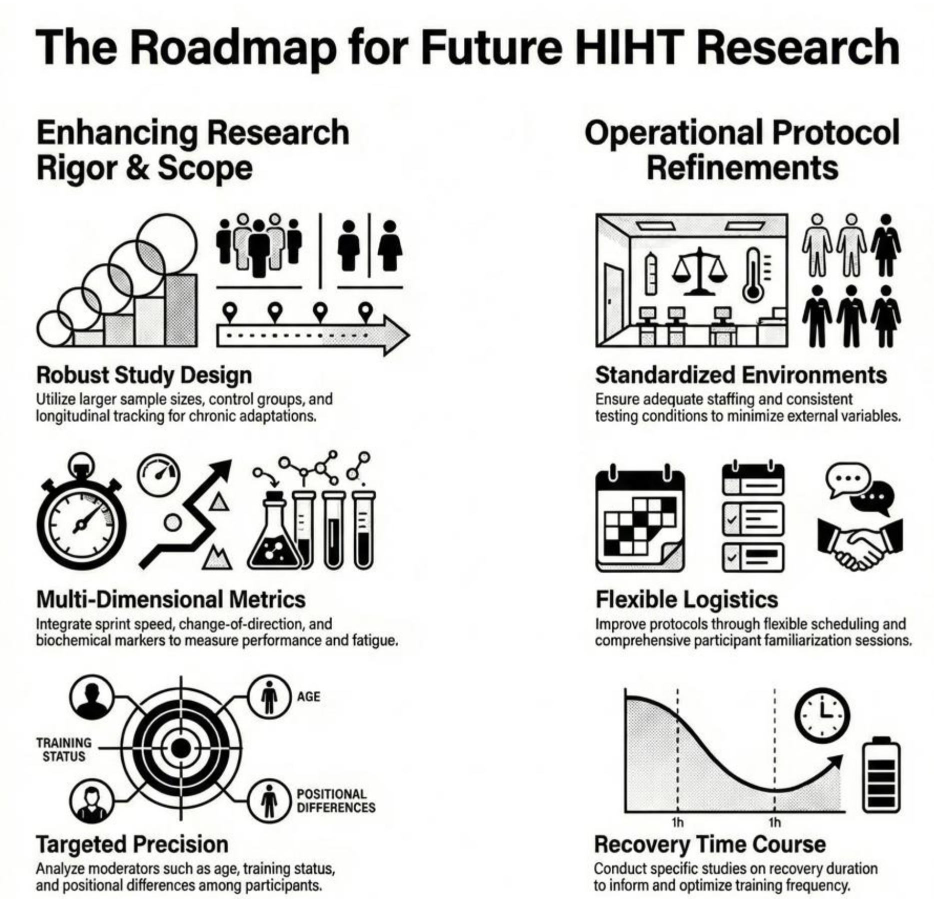

Figure 3: Direction for future study

Conclusions

This preliminary study achieved its three objectives. First, we confirmed the feasibility of conducting full-scale HIHT research in youth football players. Second, we provided initial evidence that HIHT induces significant acute fatigue, with squat jump performance decreasing 34.7% post-training. Third, we identified operational challenges, including scheduling, familiarization, environment, and staffing, requiring modification for future studies.

The consistent fatigue response across sessions (30.4-39.6%) confirms HIHT protocol reliability and supports squat jump monitoring as a practical field-based assessment. These findings align with previous research on structured training during challenging periods (Madarsa et al., 2023) and performance relationships in professional players (Madarsa et al., 2020).

For practitioners, HIHT sessions require 48-72 hours of recovery before demanding training or competition. Regular neuromuscular monitoring can inform decisions about training load. When prescribed with adequate recovery, HIHT can effectively develop football-specific physical qualities (Bompa & Buzzichelli, 2019).

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References

Allen, D. G., Lamb, G. D., & Westerblad, H. (2008). Skeletal muscle fatigue: Cellular mechanisms. Physiological Reviews, 88(1), 287-332.

Altman, D. G. (1991). Practical statistics for medical research. Chapman and Hall.

Altman, D. G., Schulz, K. F., Moher, D., et al. (2001). The revised CONSORT statement for reporting randomized trials: Explanation and elaboration. Annals of Internal Medicine, 134(8), 663-694.

Atkinson, G., & Nevill, A. M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Medicine, 26(4), 217-238.

Balsalobre-Fernández, C., Glaister, M., & Lockey, R. A. (2015). The validity and reliability of an iPhone app for measuring vertical jump performance. Journal of Sports Sciences, 33(15), 1574-1579.

Balsom, P. D., Seger, J. Y., Sjodin, B., & Ekblom, B. (1992). Maximal-intensity intermittent exercise: Effect of recovery duration. International Journal of Sports Medicine, 13(7), 528-533.

Bishop, D. J. (2003). Warm up II: Performance changes following active warm up and how to structure the warm up. Sports Medicine, 33(7), 483-498.

Bishop, D. J. (2012). Fatigue during intermittent-sprint exercise. Clinical and Experimental Pharmacology and Physiology, 39(9), 836-841.

Bobbert, M. F., Gerritsen, K. G. M., Litjens, M. C. A., & Van Soest, A. J. (1996). Why is countermovement jump height greater than squat jump height? Medicine and Science in Sports and Exercise, 28(11), 1402-1412.

Bompa, T., & Buzzichelli, C. (2019). Periodization: Theory and methodology of training (6th ed.). Human Kinetics.

Bosco, C., Luhtanen, P., & Komi, P. V. (1983). A simple method for measurement of mechanical power in jumping. European Journal of Applied Physiology and Occupational Physiology, 50(2), 273-282.

Buchheit, M. (2012). Should we be recommending repeated sprints to improve repeated-sprint ability? Sports Medicine, 42(2), 169-176.

Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. Sports Medicine, 43(5), 313-338.

Burke, L. M., & Deakin, V. (2015). Clinical sports nutrition (5th ed.). McGraw-Hill.

Chamari, K., Hachana, Y., Kaouech, F., et al. (2005). Endurance training and testing with the ball in young elite soccer players. British Journal of Sports Medicine, 39(1), 24-28.

Chaouachi, A., Manzi, M., Chaalali, A., et al. (2012). Determinants analysis of change-of-direction ability in elite soccer players. Journal of Strength and Conditioning Research, 26(10), 2667-2676.

Clansey, N. P., Hanlon, M. J., Wallace, E. S., & Lake, M. J. (2012). Effects of fatigue on running mechanics associated with tibial stress fracture risk. Medicine and Science in Sports and Exercise, 44(10), 1917-1923.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Lawrence Erlbaum Associates.

Cohen, J. (1992). A power primer. Psychological Bulletin, 112(1), 155-159.

Coutts, A. J., Wallace, L. K. M., & Slattery, K. M. (2007). Monitoring changes in performance, physiology, biochemistry, and psychology during overreaching and recovery in triathletes. International Journal of Sports Medicine, 28(2), 125-134.

Drust, B., Waterhouse, J., Atkinson, G., Edwards, B., & Reilly, T. (2005). Circadian rhythms in sports performance: An update. Chronobiology International, 22(1), 21-44.

Durlak, J. A. (2009). How to select, calculate, and interpret effect sizes. Journal of Pediatric Psychology, 34(9), 917-928.

Edwards, A. M., Challis, N. V., Chapman, J. H., Fillingham, D. B., & Manson, R. (2011). The 'informed' mouthful: A new paradigm for informed consent? British Journal of Sports Medicine, 45(2), 113-117.

Eston, R. G., Rowlands, A. V., & Ingledew, D. K. (1998). Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children's activities. Journal of Applied Physiology, 84(1), 362-371.

Faigenbaum, A. D., Lloyd, R. S., & Oliver, J. L. (2020). Essentials of youth fitness. Human Kinetics.

Field, A. (2018). Discovering statistics using IBM SPSS statistics (5th ed.). SAGE Publications.

Fisher, R. A. (1970). Statistical methods for research workers (14th ed.). Hafner Publishing Company.

Fitts, R. H. (2008). The cross-bridge cycle and skeletal muscle fatigue. Journal of Applied Physiology, 104(2), 551-558.

Foster, C., Florhaug, J. A., Franklin, J., et al. (2001). A new approach to monitoring exercise training. Journal of Strength and Conditioning Research, 15(1), 109-115.

Gabbett, T. J. (2016). The training-injury prevention paradox: Should athletes be training smarter and harder? British Journal of Sports Medicine, 50(5), 273-280.

Gandevia, S. C. (2001). Spinal and supraspinal factors in human muscle fatigue. Physiological Reviews, 81(4), 1725-1789.

Gathercole, R., Sporer, B., Stellingwerff, T., & Sleivert, G. (2015). Alternative countermovement-jump analysis to quantify acute neuromuscular fatigue. International Journal of Sports Physiology and Performance, 10(1), 84-92.

Halson, S. L. (2014). Monitoring training load to understand fatigue in athletes. Sports Medicine, 44(2), 139-147.

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. Sports Medicine, 30(1), 1-15.

Hopkins, W. G., Hawley, J. A., & Burke, L. M. (1999). Design and analysis of research on sport performance enhancement. Medicine and Science in Sports and Exercise, 31(3), 472-485.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. Medicine and Science in Sports and Exercise, 41(1), 3-13.

Ioannidis, J. P. A. (2005). Why most published research findings are false. PLoS Medicine, 2(8), e124.

Jeffreys, I. (2012). Warm-up and flexibility training. In J. R. Hoffman (Ed.), NSCA's guide to program design (pp. 37-64). Human Kinetics.

Jiménez-Reyes, P., Pareja-Blanco, M., Cuadrado-Peñafiel, F. (2016). Jump height loss as an indicator of fatigue during sprint training. Journal of Sports Sciences, 34(11), 1029-1037.

Kirkendall, D. T., & Garrett, W. E. (2018). The anterior cruciate ligament enigma: Injury mechanisms and prevention in soccer. In M. Williams (Ed.), Science and soccer: Developing elite performers (pp. 163-176). Routledge.

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. Journal of Chiropractic Medicine, 15(2), 155-163.

Lambert, M. I., & Swanepoel, J. H. (2008). The health of the athlete: From training to recovery. In M. P. Schwellnus (Ed.), The Olympic textbook of medicine in sport (pp. 289-306). Wiley-Blackwell.

Laursen, P. B., & Buchheit, M. (2019). Science and application of high-intensity interval training: Solutions to the programming puzzle. Human Kinetics.

Lloyd, R. S., & Oliver, J. L. (2012). The youth physical development model: A new approach to long-term athletic development. Strength and Conditioning Journal, 34(3), 61-72.

Lloyd, R. S., Oliver, J. L., Faigenbaum, A. D., et al. (2015). Long-term athletic development- Part 1: A pathway for all youth. Journal of Strength and Conditioning Research, 29(5), 1439-1450.

Madarsa, N. I., Abd Malek, N. F., Alali, A. A., Baki, M. H., & Mohamad, N. I. (2023). A case study: Resistance training effect on muscle mass and body fat percentage among youth football players during fasting month. International Journal of Human Movement and Sports Sciences, 11(3), 634-642.

Madarsa, N. I., Mohamad, N. I., Abd Malek, N. F., & Nadzalan, A. M. (2020). Relationship between sprint time, cardiovascular fitness and sRPE during in-season's training among professional soccer players. European Journal of Molecular & Clinical Medicine, 7(3), 4895-4904.

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). Growth, maturation, and physical activity (2nd ed.). Human Kinetics.

Markovic, G., Dizdar, D., Jukic, I., & Cardinale, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. Journal of Strength and Conditioning Research, 18(3), 551-555.

Meeusen, R., Duclos, M., Foster, C. (2013). Prevention, diagnosis, and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. Medicine and Science in Sports and Exercise, 45(1), 186-205.

Minett, G. M., & Duffield, R. (2014). Is recovery driven by central or peripheral factors? A role for the brain in recovery following intermittent-sprint exercise. Frontiers in Physiology, 5, 24.

Mohr, M., & Krustrup, P. (2018). High-intensity training in football: Principles, effects, and applications. In M. Williams (Ed.), Science and soccer: Developing elite performers (pp. 217-232). Routledge.

Nascimento, W. F. R., Silva, M. N., Nakamura, F. Y. (2020). Training load and recovery status in soccer players: A systematic review. International Journal of Sports Medicine, 41(8), 511-522.

National Strength and Conditioning Association. (2018). NSCA's essentials of personal training (3rd ed.). Human Kinetics.

Nieman, D. C. (2000). Exercise immunology: Future directions for research. International Journal of Sports Medicine, 21(S1), S1-S4.

Oliver, J. L., Lloyd, R. S., & Meyers, M. C. (2020). Training elite child athletes: Welfare and well-being. In R. C. J. A. Meeusen (Ed.), Elite youth sport (pp. 135-148). Routledge.

Schulz, K. F., Altman, D. G., & Moher, D. (2010). CONSORT 2010 statement: Updated guidelines for reporting parallel group randomized trials. BMJ, 340, c332.

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). Biometrika, 52(3-4), 591-611.

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. Journal of Sports Sciences, 24(9), 919-932.

Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. Psychological Bulletin, 86(2), 420-428.

Silva, M. N., Nascimento, W. F. R., Nakamura, F. Y., et al. (2020). Effects of high-intensity interval training on physical performance in soccer players: A systematic review. Journal of Strength and Conditioning Research, 34(3), 876-891.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. Sports Medicine, 35(6), 501-536.

Twist, C., & Highton, J. (2013). Monitoring fatigue and recovery in rugby league players. International Journal of Sports Physiology and Performance, 8(5), 467-474.

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. JAMA, 310(20), 2191-2194.

Young, W. B., James, R., & Montgomery, I. (2002). Is muscle power related to running speed with changes of direction? Journal of Sports Medicine and Physical Fitness, 42(3), 282-288.