Short-term effects of ‘composite’ training on strength, jump and sprint performance in hurling players

Abstract

The purpose of this study was to compare the short-term effects of 'composite' training to sprint training on strength, jump and sprint acceleration performance in hurling players. A randomized counterbalanced group design with baseline-, pre- and post-test measures was employed. Twenty-five hurling players volunteered to participate and 21 completed the study. Subjects were divided into a 'composite' (COMP group, n = 10) or a sprint training (SPRINT group, n = 11) group. Both groups trained twice per week for 7-weeks with the SPRINT group performing 6 repetitions of 20m sprints and the COMP group completing 6 repetitions (1-repetiton = 3 bounce drop-jumps (BDJs) with a 20 m sprint after 15 s recovery). Significant differences existed pre- to post -training for the COMP group for BDJ contact time (-7.25%; p = 0.05) and countermovement jump (CMJ) variables (height: 7.43%, p = 0.006; force: 5.24%, p = 0.05; power: 15.11%, p = 0.001).No significant differences were found between groups at baseline and for group by time interactions. Significant improvements were observed pre- to post-training in both groups for the following: absolute three repetition maximum (3RM) back squat strength (12.73-17.62%, p = 0.01), 5 m (5.74-9.49%, p = 0.006-0.04), 10 m (4.27-5.59%, p = 0.007-0.02), 20 m (3.35-3.98%, p = 0.003-0.01). In conclusion, 'composite' training is effective in enhancing fast stretch-shortening cycle (SSC) efficiency inducing CMJ force and power augmentation. However, 'composite' and sprint training are effective training approaches for enhancing maximal strength and sprint performance in a time efficient manner in hurling players.

Keywords:

Sprinting; neuromuscular; bounce drop-jump; stretch-shortening cycle; hurling.

Introduction

Hurling is a major field sport in Ireland played at amateur level. This field sport has previously been described as one of the most dynamic and skilled sports played in the world (25). The play in hurling can change rapidly, due to the large distances the ball can be struck (90-100 m), which is distinct from other field sports (Field hockey, lacrosse and soccer) (34). The physical demands of hurling require a high level of performance conditioning with a particular emphasis in areas of vertical jumping and sprint acceleration (17). Furthermore, athletes are also required to have appropriate levels of aerobic power to compete (34). However, strength, jumping and the ability to accelerate are evident where jumping ability is necessary to contest aerially for ball possession and to accelerate over short distances in these critical decisive offensive and defensive situations as they occur close to the ball and can determine the outcome of match-play (34). Sprint accelerations are an explosive action performed on average 62 times in a match situation (16). Furthermore, jumping ability is necessary to contest possession of the ball in the air. As such, high maximum strength (absolute and relative) and power-related qualities are crucial for high-level performance in hurling competition. This highlights the need for appropriate training programs that can enhance these physical qualities in hurling athletes, however research into these programs is currently conspicuous by its absence.

Researchers have shown that various sprint stand alone or combination training programs (an explosive activity such as a jump combined with a sprint) improved speed in netball, rugby league, rugby union and soccer (3); countermovement jump (CMJ) height and speed in soccer (24) and strength (maximum and reactive) and speed in football codes such as Australian rules football, rugby union and soccer (30). A study on field and team sport (Australian rules football, rugby union and soccer) athletes included sprint and resisted sprint training groups which completed two sessions per week for 6-weeks (30). These groups completed the same volume of sprint training each week, with sprint distances ranging from 5 to 20 m and the weekly distance volume progressively increased over the 6-week study. Both the sprint and resisted sprint training groups displayed significant improvements in strength (maximum and reactive) and sprinting performance. When considering combination training program studies, the number of studies is limited and the findings are mixed (3, 24). One study compared back squats with CMJs and sprints to hack squats with CMJs and sprints to CMJs and sprint training alone (3). This study found no significant differences between the groups for jump and sprint performance; however, all groups showed a significant improvement in 10 m sprint performance. The authors suggested that the non-significant difference been groups was because of the training period been insufficient in duration for exercise movement patterns to have an effect. Conversely, combining loaded squat jumps (SJ) and agility training, with unresisted sprint training or resisted sprint training induced a significant enhancement in CMJ and sprint performance in professional soccer athletes (24). This study hypothesized that resisted sprint training would be more effective than unresisted sprint training on sprint and agility performance, however, this was not the case. The reasons offered for resisted sprint producing similar improvements to unresisted sprinting were insufficient overload applied over the training period and fatigue from soccer specific training during the study may have reduced the training effect of the resisted sprinting. However, bounce drop-jumps (BDJ) employing the fast stretch-shortening cycle (SSC) (4) performed with a vertical displacement followed by a sprint subsequent to a rest period have not been studied over a short-term training period. Furthermore, adaptations to this form of training over a short-term period have not been investigated on maximal strength, reactive strength and alterations in CMJ kinetic and kinematic parameters.

Despite a lack of research into combining BDJs with a sprint to improve strength and power qualities in hurling athletes over a short-term period, acute studies have shown the effectiveness of a reduced volume of BDJs in conjunction with brief recovery on jump and sprint performance (8, 14). Furthermore, two studies examining the acute response to a single ‘composite’ session have shown that 20 m sprint performance and relative maximum strength (9) and maximum strength (absolute and relative) (10) were significantly enhanced following 7-days of recovery post-session. Thus, the effectiveness of combining BDJs with a sprint requires investigation over a short-term period, which led to the development of a novel term, ‘composite’ training (COMP). COMP training can be defined as the combination of a plyometric exercise with an explosive activity such as a sprint run, performed as a ‘combined repetition’ / session (9). This form of training is underpinned by post activation potentiation (PAP), which is a phenomenon where acute muscle performance is enhanced because of the muscles’ contractile history (35). Therefore, the purpose of this study was to investigate the short-term effects of COMP training on maximal strength, reactive strength, jump and sprint acceleration performance. It is hypothesized that COMP training would enhance maximal strength, reactive strength and jump performance to a greater degree when compared to sprint acceleration training only.

Methods

Experimental approach to the problem

This study investigated a 7-week intervention of COMP, in comparison to sprint training (SPRINT), on three repetition maximum (3RM) back squat strength, CMJ performance, reactive strength index (RSI) and sprint acceleration performance (5, 10 and 20 m times). The study was conducted using a randomized, counterbalanced group design, with repeated measures, by ranking the subjects from highest to lowest based upon 20m sprint times and dividing them into COMP and SPRINT groups.

Subjects

Twenty-five male hurling athletes (mean ± SD: age = 22.10 ± 3.19 years; mass = 77.30 ± 7.35 kg; height = 1.80 ± 0.06 m) competing in the Irish collegiate league season and at club level volunteered to participate in the study. Of these twenty-five hurling athletes, twenty-one athletes completed the study due to time constraints or injury not related to the study (mean ± SD: age = 21.80 ± 2.90 years; mass = 76.60 ± 7.37 kg; height = 1.79 ± 0.06 m). Subjects were requested to undertake their normal hurling training during the study, which comprised of an average of three training sessions and one match per week. Resistance training was performed on average on two occasions per week and subjects had a minimum of one year’s resistance training experience. Subjects’ reported no orthopedic or musculoskeletal injuries to the lower body, in the six months prior to data collection and written consent was obtained from all subjects. Ethical approval was provided by the institutional ethics committee.

Procedures

A week before baseline testing, subjects were familiarized with the testing and training procedures. A dynamic warm-up was performed before familiarization, testing and training and comprised of five minutes of self-paced low intensity jogging over 10m, followed by a protocol of five dynamic stretches targeting the gluteals, hamstrings, adductors, quadriceps and gastrocnemius muscles (40). There was a period of 7-days between baseline and pre-testing; the pre- and post-testing were performed within 7-days of the commencement and completion of the training program. Subjects in both groups attended two conditioning sessions 48-72 hours apart per week (12). The COMP group performed six repetitions of ‘composite’ training (One repetition comprised 3 BDJs followed by a 20 m sprint subsequent to a 15 s rest interval) with a 4-min inter-repetition recovery (9, 22). The SPRINT group performed six 20 m sprints with 4-mins recovery (6 repetitions). Subjects were expected to perform the jumps at maximum effort and the sprints were performed at 90-95% of self-selected maximum intensity at each session. The 90-95% of self-selected maximum intensity is as per Bompa and Haff (5). All sessions were supervised by the lead author. To maximize jump and sprint performance, the following coaching instructions were provided before each repetition of the BDJs and sprints: BDJs - “minimize ground contact time (GCT) and maximize jump height” and “pre-tense the leg muscles before landing”; sprinting - “drive away from the start line as fast as possible” (2, 7).

CMJ testing

CMJ testing was performed first and required subjects to perform three maximal CMJs by squatting to a self-selected depth followed by jumping upward for maximum height. A 15 s rest was provided between the three CMJ trials (33). Subjects were required to take-off and land on the same portable force plate and required arms to be akimbo for the entire jump movement (Type 92886AA, Kistler Instruments Ltd, Hook, United Kingdom). Three trials were performed and the best trial, based upon jump height, was used for subsequent analysis.

Reactive Strength Index Testing and Drop Height Determination

After completing the CMJ test, a 2-min recovery was allowed before all subjects performed a BDJ test on a portable force plate, to determine their maximum RSI and to identify drop height for the BDJs to be performed by the COMP group. Two BDJs from five different drop heights (0.20 m, 0.30 m, 0.40 m, 0.50 m and 0.60 m) were performed using an incremental protocol; employed so that the stretch load (intensity) could be progressively increased. Two minutes of rest was permitted between drop heights to minimize fatigue (43). The highest RSI of two BDJs for each drop height was used for analysis. Drop height was determined by employing the RSI method (11); which identifies the drop height to be used as the height that produces the maximum RSI. GCT for each BDJ jump was required to be < 0.250s (37).

Sprint testing

Prior to maximal sprint acceleration effort testing and training in both groups, subjects performed a sprint warm-up comprising of two sprints at 50%, and three at 80% of maximum over 20 m on a synthetic indoor track in the laboratory (42). Subjects were allowed 30 s recovery between the 50% sprints, 1-min recovery between the 80% sprints, and 1-min recovery between the final 80% sprint and the first maximal sprint effort. Maximal 20 m sprinting began with subjects in a static upright position 0.5 m behind the first Witty photocell (Microgate, Bolzano, Italy) and were instructed when to start. Three maximal sprints were performed with 3-mins recovery and times were collected at 5, 10, and 20 m with the fastest times used for analysis.

Maximum back squat strength testing

After the third maximal 20 m sprint was completed, a 3-min recovery period was allowed before the subjects performed a modified 3RM back squat strength test protocol (19). Subjects were required to back squat, with a loaded barbell across their shoulders, until their knee axis was in-line with their hip axis in relation to the horizontal. Warm-up sets began with two sets of eight repetitions at 50% of predicted 1RM followed by four repetitions with 70% 1-RM. Following completion, subjects attempted to perform three repetitions at a 3RM load. A 2-min recovery period and a 5-min recovery were allowed between the warm-up sets and the 3RM attempts respectively. The 3RM trials continued until the subject was unable to complete the lift through the designated range of movement. Relative strength was calculated as: relative strength = 3RM (kg)/body mass (kg).

Data analysis

A portable multi-component force plate with a built-in charge amplifier (Type 92886AA, Kistler Instruments Ltd, Hook, United Kingdom) was used to measure force-time indices at a sampling frequency of 1000 Hz. Data were saved and analyzed using bespoke BTS-SMART software (BTS Spa, Milan, Italy). The measures of jump height, peak velocity, peak force, peak power and average eccentric rate of force development (ECC-RFD) were calculated from the CMJ test data. These variables were selected to examine how COMP and SPRINT training may affect neuromuscular adaptations which in turn may enhance jump and sprint performance (13, 18, 29). Variables were derived as absolute and relative values except for jump height and peak velocity. Relative values were expressed relative to body mass (kg). Peak force was considered as the highest ground reaction force in the vertical component during the concentric phase of the jump. Peak power was computed from the product of peak force and peak velocity of the center of mass from the CMJ. To calculate peak velocity, center of mass velocity was derived from the numerical integration of vertical acceleration; calculated by dividing the vertical ground reaction force by the subject's body mass. ECC-RFD was calculated during the eccentric phase of the CMJ, from the force-time curve, when force exceeded body weight (N), and ended when velocity was equal to zero (bottom of descent before moving in an upward direction towards take-off) (27). Jump height (H) for the CMJ and BDJ was calculated from flight time using the following equation (6):

$H = (gt^2)/8$ where: g = acceleration due to gravity ($9.81 ms^{-2}$); t = flight time (s).

GCT during the ground contact phase (the timeframe in which a subject is in contact with the ground before the subsequent jump) was calculated as the time between initial foot contact and take-off (21). The RSI was calculated as follows: RSI = jump height (m)/contact time (s).

Statistical analyses

Data are summarized as means ± SDs for all measures. A three (time: baseline, pre-session and post-session) by two (groups: COMP and SPRINT) within-between repeated measures ANOVA was performed to determine if significant differences existed for the main effect of composite training versus sprint training over a 7-week training period. If Mauchley's test of Sphericity was violated the Greenhouse-Geisser was used (20 m sprint time, 3RM back squat strength and CMJ absolute and relative power). Effect sizes (partial eta) and power are also provided for each of the comparisons. *Post-hoc* pair-wise comparisons were conducted using a Dunn-Sidak adjustment to the level of significance. Effect size was calculated using Cohen’s *d* where the mean of the differences between the pre-test and the post-test scores were divided by the respective pooled SD. Effect sizes were interpreted as <0.2 = trivial, 0.2-0.5 = small, 0.5-0.8 = moderate, and 0.8 ≥ = large (15). CMJ, BDJ, 3RM back squat strength test and 20 m sprint performance measures were found to be reliable based upon ICC values ranging from 0.88 to 0.99. Statistical significance was set at p ≤ 0.05 and data were analyzed using the Statistical Package for the Social Sciences Version 23 (SPSS Inc., Chicago, Illinois).

Results

There were no significant differences between groups at baseline for 3RM back squat strength, CMJ height and sprint (5, 10 and 20 m). However, the COMP group had significantly faster sprint times compared to the SPRINT group pre-training, for 5 and 10 m sprint times (5 m: p = 0.02; 10 m: p = 0.04).

No significant effects for group and time by group were found for 3RM back squat strength (absolute and relative), BDJ performance (RSI, jump height and GCT), all CMJ measures and all sprint performance measures.

GCT showed a significant time effect ($F_{2, 38}$ = 3.06; p = 0.05; partial eta = 0.13; power = 0.55). A significant decrease occurred in the COMP group from pre- to post-training (t_{9} = 2.20; p = 0.05; Table 2 and Figures 1 and 2).

*****Table 2 about here*****

A significant time effect existed for absolute ($F_{1.12, 21.33}$ = 30.26; p = 0.0001; partial eta = 0.61; power = 1.0) and relative ($F_{1.15, 21.97}$ = 25.90; p = 0.0001; partial eta = 0.57; power = 0.99) 3RM back squat strength. Pair-wise comparisons showed a significant increase in absolute and relative 3RM back squat strength from baseline to post-training (Absolute 3RM; COMP group: p = 0.004, SPRINT group: p = 0.01. Relative 3RM; COMP group: p = 0.005, SPRINT group: p = 0.01) and from pre- to post-training (Absolute: COMP group: p = 0.01; SPRINT group: p = 0.01. Relative 3RM: COMP group: p = 0.02; SPRINT group: p = 0.02) (Table 4 and Figures 1 and 2).

*****Table 4 about here*****

A significant time effect was present for CMJ height ($F_{1.51, 28.82}$ = 22.09; p = 0.0001; partial eta = 0.53; power = 1.0), peak velocity ($F_{1.35, 25.80}$ = 6.79; p = 0.009; partial eta = 0.26; power = 0.79), peak force ($F_{2, 38}$ = 4.57; p = 0.01; partial eta = 0.19; power = 0.74), peak power ($F_{1.36, 25.99}$ = 10.36; p = 0.002; partial eta = 0.35; power = 0.93) and relative peak power ($F_{1.42, 27.03}$ = 6.70; p = 0.009; partial eta = 0.26; power = 0.80). Pair-wise comparisons showed a significant increase for height, from baseline to post-training (height: p = 0.002) and from pre- to post-testing in the COMP (height: p = 0.006; velocity: p = 0.04; force: p = 0.05; power: p = 0.001; relative power: p = 0.002) and the SPRINT group (velocity: p = 0.02) (Table 1 and Figures 1 and 2).

*****Table 1 about here*****

A significant time effect was observed for 5 m ($F_{2, 38}$ = 19.46; p = 0.0001; partial eta = 0.50; power = 1.0), 10 m ($F_{2, 38}$ = 21.06; p = 0.0001; partial eta = 0.51; power = 1.0) and 20 m sprint times ($F_{2, 38}$ = 24.99; p = 0.0001; partial eta = 0.56; power = 1.0). The results of the pairwise comparisons showed that no significant change occurred from baseline to pre-test for 5, 10 and 20 m sprints for both groups. However, a significant decrease was evident between baseline and post-training (COMP: 5 m: $p = 0.01$; 10 m: $p = 0.004$; 20 m: $p = 0.009$; SPRINT: 5 m: $p = 0.002$; 10 m: $p = 0.007$; 20 m: $p = 0.001$) and between pre and post-training (COMP group: 5 m: $p = 0.04$, 10 m: $p = 0.02$, 20 m: $p = 0.01$; SPRINT: 5 m: $p = 0.006$, 10 m: $p = 0.007$, 20 m: $p = 0.003$) (Table 3 and Figures 1 and 2).

*****Table 3 and figure 1 about here*****

Discussion

The current study investigated the effect of COMP training, a novel programming approach, over a 7-week period to enhance 3RM back squat strength, RSI, CMJ and sprint performance in hurling athletes. COMP training was found to be effective in reducing GCT and enhancing CMJ measures pre- to post-training (height, velocity, peak force and peak power) in hurling players. Furthermore, COMP and SPRINT training proved effective in enhancing 3RM back squat strength and sprinting (5, 10 and 20 m) performance. These findings do not support our hypothesis that ‘composite’ training would be more effective than sprint training.

When considering fast SSC function through BDJ performance, RSI in the COMP and SPRINT groups improved non-significantly, however, a previous study exhibited a significant improvement (30). In the aforementioned study, subjects performed a slow SSC DJ from a pre-determined drop height as GCTs were >0.250 s which induced a significant RSI improvement. The current study confirmed the COMP group significantly improved GCT leading to improved SSC performance. This adaptation is possibly due to the performance of BDJs from an individualized drop height, which enhanced the efficiency of elastic energy contribution due to a shorter transition period between the eccentric and concentric phases eliciting a potentiation effect (4). Moreover, subjects were instructed to pre-tense the lower limbs prior to ground contact, which can enhance pre-activation of the muscles before the eccentric phase which is a fundamental SSC condition (26). This muscular pre-activation may have led to eccentric muscle action fiber adaptation where increased force generation may be due to the activation of a second myosin head to actin increasing the number of active cross-bridges, and because of increased titin stiffness from the binding of calcium to titin (20, 28). The COMP group GCT findings, suggest that these mechanisms induce force and power potentiation, which can augment CMJ and sprint performance in hurling athletes (29).

The present study confirms absolute and relative 3RM back squat strength improved significantly in both groups, which corroborates previous work (30). The SPRINT results are in agreement with previous work where field and team sport athletes (Australian rules football, basketball, handball, rugby union and soccer) performed sprint and resisted sprint training alone (30, 31). These maximal strength gains may consequently be from improved intermuscular co-ordination and increased concentric strength, where significant relationships exist between horizontal force production and gluteus concentric strength and activity during initial acceleration (first 10 steps in a sprint) (32, 44). The enhanced maximal strength in both groups appears to have transferred to improved sprint acceleration performance which has been reported previously (39).

The SPRINT group did not show a significant improvement pre- to post-training for CMJ height, which is in agreement with previous work (30). However, the COMP group experienced a significant enhancement in CMJ height, which provides an alternative exercise to loaded SJs in combination with sprints (24). The type, volume and loading of the jumps differed between the current study and the aforementioned study, where they reported substantially higher jump enhancement (15%) following a 6-week training intervention. However, the study by Gil et al. (24) employed a greater volume of jumps, loaded the jumps and had professional soccer athletes perform additional weekly plyometric sessions. Such differences may explain the greater magnitude of CMJ enhancement. A PAP review has suggested that a greater volume (multiple sets and greater repetitions) of a conditioning exercise such as loaded SJs is more effective for a weaker strength level even though maximal strength was not reported in the aforementioned study (38). Comparing kinetic and kinematic measures between the current study and the aforementioned studies was not possible as, to the knowledge of the authors, this was the first study to investigate these measures when employing ‘composite’ training. The COMP group showed significant augmentations in peak velocity, peak absolute concentric force and peak concentric power (Absolute and relative). These findings suggest that the inclusion of BDJs in ‘composite’ training is effective at improving the force and velocity components of the force-velocity curve, which improved concentric power through a decrease in BDJ GCT. However, the inclusion of 18 BDJs per session in the COMP group proved to be more effective for power production in comparison to plyometric training alone, which highlights that combined forms of training appear to be more efficient and effective for athletes and certainly hurling athletes (13). The potentiation of CMJ force and power in the COMP group may be underpinned by increases in motor unit firing frequency, which can enhance eccentric power during a CMJ and supports the suggested effects of motor unit discharge rates on eccentric strength (1). In addition, improvements in motor unit synchronization (intramuscular coordination) and intermuscular coordination (improved synergist co-activation and decreased antagonist co-activation) can assist in expressing neuromuscular power (18).

Our findings for improved sprint performance support previous work that investigated the training effect of sprint, resisted sprint, combined jump-sprint and combined jump-agility-sprint training (3, 24, 30). These studies requested subjects perform a greater sprint distance volume per week compared to the current study. The volume of sprinting in a session is critical and can have considerable effects on physiological/neurological performance, thus potentially affecting other programming variables (i.e. recovery time and weekly frequency) and impacts upon total session training time which is a limiting factor for collegiate/club level hurling athletes. The findings provide evidence that a limited volume of sprint accelerations is effective in enhancing sprint performance in hurling athletes as suggested by previous work (9). However, the volume and / or sprint distances used in COMP training should be examined to determine if shorter distances would be as effective from a dose-response perspective. The adaptations in sprint performance in the current study illustrates the importance of dynamic correspondence (41). Furthermore, the significant enhancement in absolute and relative strength appears to have induced improvements in sprint performance in both groups of this study (39). The SPRINT group experienced a greater improvement especially in 5 m sprint time. Explanations for this difference are due to the pre-training 5 and 10 m sprint times for the COMP group being significantly lower than the SPRINT group, which was attributed to subject withdrawal, which offered a reduced capacity for sprint performance enhancement. Moreover, the attenuated improvement in 5 and 10 m times in the COMP group may be due to genetics (muscle fiber typing) (35). SPRINT and COMP group sprint acceleration enhancement may have transpired through muscle architectural adaptations where pennation angle is decreased and fascicle length and thickness increased (3). Neural adaptations possibly responsible include; changes in temporal sequencing of muscle activation for more efficient movement, preferential recruitment of the fastest motor units, increased nerve conduction velocity, frequency of muscle innervations, and improved capacity to maintain muscle recruitment and rapid firing throughout the sprint (36). Future research could consider surface electromyography to quantify the potential magnitude and pattern of surface muscle activity following a period of ‘composite’ and sprint training.

A limitation of the current study was the additional training undertaken by the subjects during the study in the form of hurling pitch sessions, weekly matches and resistance training. This additional training occurred as subjects were involved in the Irish collegiate league season and club level competition. Furthermore, to conduct the current study when no additional training occurs is challenging as generally a transition phase is not part of the annual training hurling cycle to enable players time to recover. Thus, the findings of the current study need to be taken into context in relation to the concurrent training of hurling sessions and ‘composite’ or sprint training by the hurling players. A previous review has found that concurrent training factors that may affect study findings include player training status; programming variables (i.e. volume, intensity, recovery, training modality and the program duration); measures used to assess changes in strength, power and RFD; and the adaptations that transpired (23). Thus, the SPRINT group in the current study may have experienced augmented adaptations due to the concurrent training, which potentially included explosive movements that were similar in nature to the COMP group. The concurrent training performed by the COMP and SPRINT groups was beyond the control of the authors and a concurrent only control group was not included. Consequently, future research should include controlled concurrent training and to include a control group which only performs concurrent training.

In summary, COMP training results in a decrease in BDJ GCT which appears to have transferred to improved jump performance in hurling athletes. Furthermore, these adaptations are underpinned by improved SSC performance and augmented peak velocity, force and power. Both the COMP and SPRINT training groups experienced significant gains in maximal leg strength and sprint acceleration performance. This study has shown that dynamic correspondence is an important principle and must be considered dependent on the explosive qualities required for the sport (41). Further research should consider the direction of displacement of a plyometric exercise employed, in conjunction with a sprint acceleration distance dependent on the objectives of the athlete, coach and sport science practitioner.

*****Figure 2 about here*****

Practical Applications

A 7-week intervention training period of two sessions per week resulted in ‘composite’ and sprint training significantly improving maximal strength and sprint acceleration performance (5, 10 and 20 m) in collegiate and club level hurling athletes. Furthermore, ‘composite’ training causes a decrease in fast SSC GCT and a significant rise in CMJ height due to increases in peak velocity, force and power. ‘Composite’ training appears to have assisted hurling players in employing a CMJ strategy where both peak force and peak velocity are targeted to maximize power and height. The current study has shown that sprint training alone is effective at improving strength and sprint performance in hurling players. When considering ‘composite’ training in this study, the duration was short (~25 min) and provides the hurling coach and sport science practitioner with an alternative, effective and time-efficient approach to enhance strength, jump and sprint performance, crucial qualities required for successful performance in hurling.

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Figure legends.

Figure 1. Pre- to post- percentage changes (mean ± SD) for the CMJ, BDJ, strength and sprint measures for the COMP and SPRINT groups.

Note: A – sprint measures: B – strength measures; C – CMJ measures (HT – height, PV – peak velocity, PF – peak force, RPF – relative peak force, PP –peak power, RPP – relative peak power, RFD – eccentric rate of force development, RRFD – relative eccentric rate of force development); D – BDJ measures (HT – height, GCT – ground contact time, RSI – reactive strength index). a $p \leq 0.05$ decrease from pre- to post-training; b $p \leq 0.05$ increase from pre- to post-training; c $p < 0.01$ increase from pre- to post-training; d $p < 0.01$ decrease from pre- to post-training.

Figure 2. Cohen’s *d* effect sizes (95% confidence interval (CI)) pre- to post 7-weeks COMP and SPRINT training for all measures.

Note: COMP – ‘composite’ training group; SPRINT – sprint training group; HT – height; PV – peak velocity; PF – peak force; RPF – relative peak force; PP –peak power; RPP – relative peak power; RFD – eccentric rate of force development; RRFD – relative eccentric rate of force development; GCT – ground contact time; RSI – reactive strength index.

Figure 1.

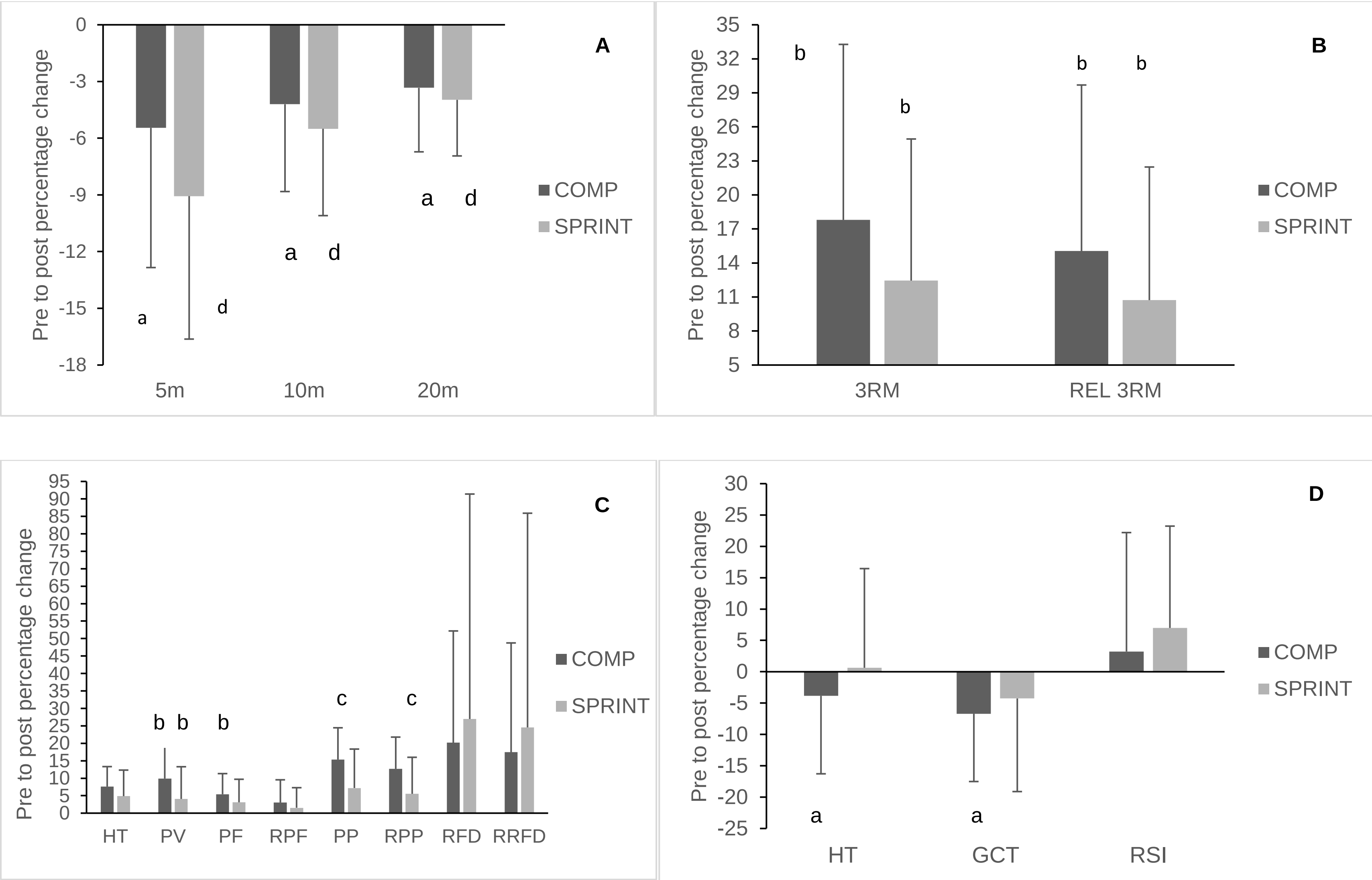
A
Pre to post percentage change
0
-3
-6
-9
-12
-15
-18
5m
10m
20m
a
d
a
d
a
d
COMP
SPRINT
B
Pre to post percentage change
35
32
29
26
23
20
17
14
11
8
5
3RM
REL 3RM
b
b
b
b
COMP
SPRINT
C
Pre to post percentage change
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
HT
PV
PF
RPF
PP
RPP
RFD
RRFD
b b
b
c
c
COMP
SPRINT
D
Pre to post percentage change
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
HT
GCT
RSI
a
a
COMP
SPRINT

Figure 2.

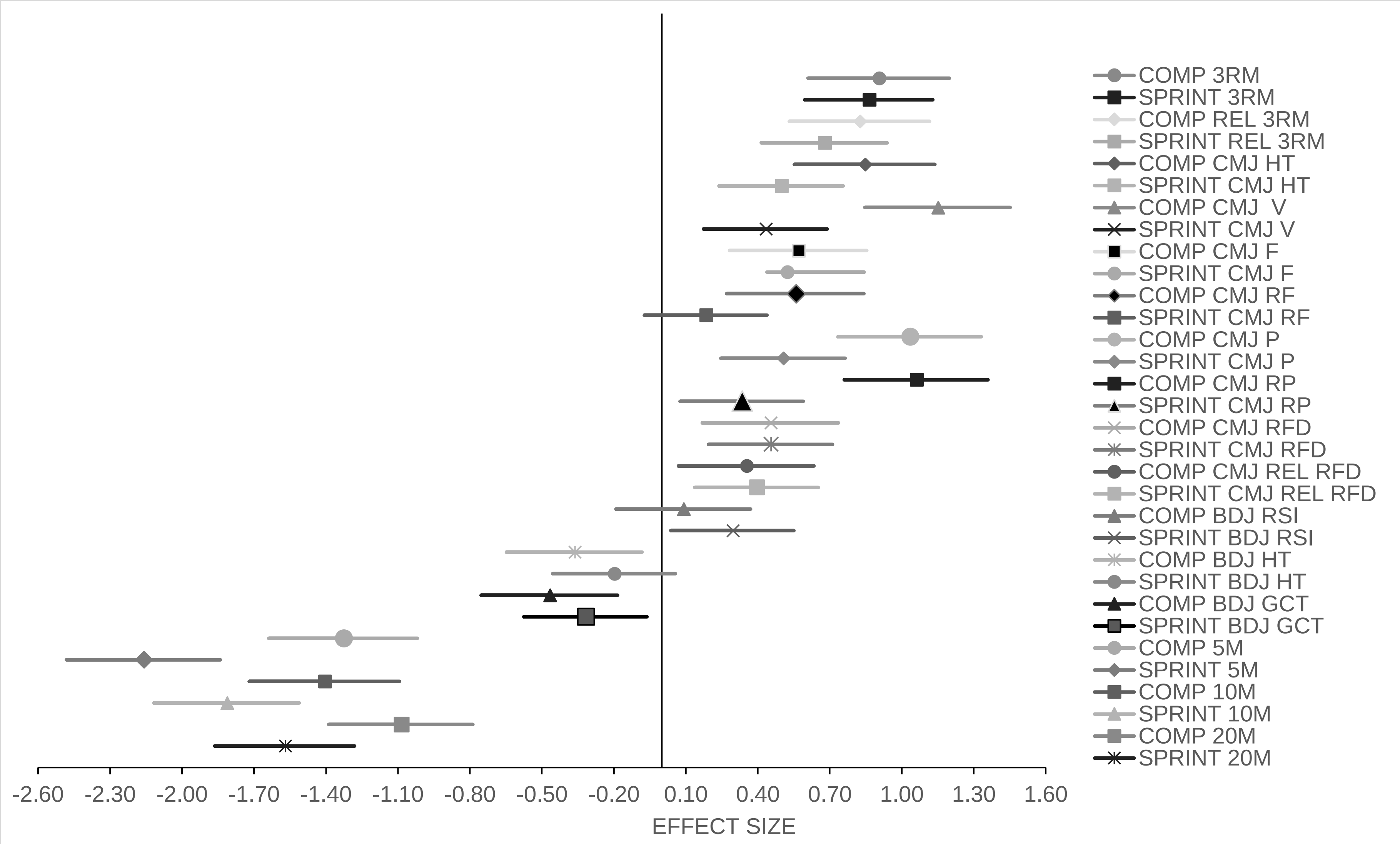
COMP 3RM
SPRINT 3RM
COMP REL 3RM
SPRINT REL 3RM
COMP CMJ HT
SPRINT CMJ HT
COMP CMJ V
SPRINT CMJ V
COMP CMJ F
SPRINT CMJ F
COMP CMJ RF
SPRINT CMJ RF
COMP CMJ P
SPRINT CMJ P
COMP CMJ RP
SPRINT CMJ RP
COMP CMJ RFD
SPRINT CMJ RFD
COMP CMJ REL RFD
SPRINT CMJ REL RFD
COMP BDJ RSI
SPRINT BDJ RSI
COMP BDJ HT
SPRINT BDJ HT
COMP BDJ GCT
SPRINT BDJ GCT
COMP 5M
SPRINT 5M
COMP 10M
SPRINT 10M
COMP 20M
SPRINT 20M
-2.60 -2.30 -2.00 -1.70 -1.40 -1.10 -0.80 -0.50 -0.20 0.10 0.40 0.70 1.00 1.30 1.60
EFFECT SIZE

Table 1. CMJ and BDJ measures (mean ± SD, 95% confidence intervals (CI)) for the COMP and SPRINT groups at baseline, pre- and post the 7-weeks of training.

	COMP			SPRINT		
	Base (95% CI)	Pre (95% CI)	Post (95% CI)	Base (95% CI)	Pre (95% CI)	Post (95% CI)
m	0.36 ± 0.04b	0.37 ± 0.03d	0.40 ± 0.04	0.37 ± 0.03	0.37 ± 0.04	0.39 ± 0.04
	(0.33-0.39)	(0.34-0.40)	(0.37-0.43)	(0.34-0.39)	(0.34-0.39)	(0.35-0.41)
m s^{-1}	2.73 ± 0.13	2.66 ± 0.17c	2.92 ± 0.27	2.68 ± 0.16	2.76 ± 0.21c	2.87 ± 0.29
	(2.65-2.83)	(2.53-2.78)	(2.72-3.11)	(2.58-2.80)	(2.63-2.91)	(2.68-3.08)
N	1740 ± 169	1705 ±155c	1795 ± 160	1833 ± 200	1812 ± 190	1863 ± 186
	(1619-1861)	(1594-1816)	(1680-1909)	(1692-1992)	(1661-1946)	(1714-1988)
N kg^{-1}	2.39 ± 0.15	2.33 ± 0.13	2.40 ± 0.12	2.41 ± 0.15	2.38 ± 0.20	2.42 ± 0.23
	(2.29-2.51)	(2.24-2.44)	(2.31-2.49)	(2.29-2.50)	(2.23-2.45)	(2.25-2.50)
W	4774 ± 587	4561 ± 620d	5250 ± 707	4941 ± 655	5018 ± 623	5361 ± 724
	(4353-5194)	(4117-5005)	(4745-5756)	(4450-5439)	(4511-5388)	(4774-5822)
W kg^{-1}	64.40 ± 5.36	61.31 ± 6.44d	68.95 ± 7.86	63.83 ± 6.58	65.13 ± 9.24	68.67 ± 11.71
	(60.57-68.24)	(56.70-65.92)	(63.33-74.59)	(58.49-67.60)	(58.14-68.34)	(59.25-74.63)
N s^{-1}	5632 ± 1952	4959 ± 1714	5628 ± 1172	5355 ± 2229	5053 ± 1816	5925 ± 2005
	(4235-7029)	(3732-6185)	(4789-6467)	(3589-6909)	(3610-5890)	(4312-6935)

N kg^{-1}	7.80 ± 2.70 (5.97-9.64)	6.84 ± 2.35 (5.20-8.47)	7.56 ± 1.65 (5.91-9.22)	7.02 ± 2.82 (5.28-8.77)	6.70 ± 2.55 (5.15-8.26)	7.82 ± 3.06 (6.24-9.40)

CMJ: m = height; m s^{-1} = peak velocity; N = peak force; N kg^{-1} = relative peak force; W = peak power; W kg^{-1} = relative peak power; N s^{-1} = eccentric rate of force development (ECC-RFD); N kg^{-1} = relative ECC-RFD. b $p < 0.01$ increase from baseline to post-training. c $p \leq 0.05$ increase from pre- to post-training. d $p < 0.01$ increase from pre- to post-training.

Table 2. BDJ measures (mean ± SD, 95% confidence intervals (CI)) for the COMP and SPRINT groups at baseline, pre- and post the 7-weeks of training.

	COMP			SPRINT		
	Base (95% CI)	Pre (95% CI)	Post (95% CI)	Base (95% CI)	Pre (95% CI)	Post (95% CI)
$m\ s^{-1}$	1.47 ± 0.23	1.48 ± 0.24	1.50 ± 0.19	1.45 ± 0.33	1.48 ± 0.30	1.58 ± 0.37
	(1.26-1.67)	(1.28-1.69)	(1.29-1.71)	(1.36-1.75)	(1.28-1.68)	(1.37-1.78)
m	0.27 ± 0.06	0.28 ± 0.06a	0.26 ± 0.05	0.27 ± 0.03	0.27 ± 0.06	0.26 ± 0.04
	(0.25-0.29)	(0.24-0.31)	(0.24-0.29)	(0.25-0.30)	(0.23-0.30)	(0.24-0.28)
s	0.188 ± 0.020	0.193 ± 0.032a	0.179 ± 0.028	0.180 ± 0.032	0.182 ± 0.029	0.173 ± 0.028
	(0.172-0.204)	(0.172-0.214)	(0.158-0.200)	(0.165-0.196)	(0.162-0.203)	(0.154-0.194)

$m\ s^{-1}$ = reactive strength index (RSI); m = BDJ height; s = ground contact time. a $p \leq 0.05$ decrease from pre- to post-training.

Table 3. Sprint performance times (s) and 3RM back squat strength (mean ± SD, 95% confidence intervals (CI)) for the COMP and SPRINT groups at baseline, pre- and post the 7-weeks of training.

	COMP			SPRINT		
	Base (95% CI)	Pre (95% CI)	Post (95% CI)	Base (95% CI)	Pre (95% CI)	Post (95% CI)
5m	1.08 ± 0.05a	1.06 ± 0.0c	1.00 ± 0.04	1.11 ± 0.04b	1.12 ± 0.06d	1.01 ± 0.04
	(1.05-1.12)	(1.02-1.10)	(0.97-1.03)	(1.07-1.14)	(1.08-1.15)	(0.98-1.04)
10m	1.82 ± 0.05b	1.80 ± 0.04c	1.72 ± 0.07	1.83 ± 0.05b	1.85 ± 0.05d	1.75 ± 0.06
	(1.79-1.86)	(1.77-1.84)	(1.68-1.77)	(1.79-1.87)	(1.82-1.88)	(1.70-1.79)
20m	3.11 ± 0.08b	3.10 ± 0.07c	3.00 ± 0.11	3.13 ± 0.07b	3.14 ± 0.06d	3.02 ± 0.09
	(3.06-3.17)	(3.05-3.15)	(2.92-3.07)	(3.07-3.18)	(3.10-3.19)	(2.95-3.09)

a $p \leq 0.05$ decrease from baseline to post-training. b $p < 0.01$ decrease from baseline to post-training. c $p \leq 0.05$ decrease from pre- to post-training. d $p < 0.01$ decrease from pre- to post-training.

Table 4. 3RM back squat strength (mean ± SD, 95% confidence intervals (CI)) for the COMP and SPRINT groups at baseline, pre- and post the 7-weeks of training.

	COMP			SPRINT		
	Base (95% CI)	Pre (95% CI)	Post (95% CI)	Base (95% CI)	Pre (95% CI)	Post (95% CI)
kg	100.30 ± 16.15f	103.30 ± 16.29g	121.50 ± 23.21	103.50 ± 11.31e	104.00 ± 10.74g	117.00 ± 19.46
	(88.74-111.85)	(91.64-114.95)	104.88-138.11)	(95.40-111.59)	(96.31-111.68)	(103.07-130.92)
kg/ BW	1.35 ± 0.06f	1.39 ± 0.21g	1.59 ± 0.27	1.32 ± 0.14e	1.33 ± 0.14g	1.47 ± 0.27
	(1.20-1.50)	(1.23-1.54)	(1.40-1.78)	(1.22-1.42)	(1.22-1.43)	(1.28-1.66)

e $p \leq 0.05$ increase from baseline to post-training. f $p < 0.01$ increase from baseline to post-training. g $p \leq 0.05$ increase from pre- to post-training.