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The effect of equipment modification on the performance of novice junior cricket batters

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Abstract

Equipment scaling has yielded better performance in children in comparison to using adult equipment. To better inform applied practice in junior sport, an investigation of additional equipment modifications designed to further simplify the task is required. This study therefore aims to determine the effect of increasing surface area of cricket equipment (bats and balls) on batting performance and technique. Forty three children (M_{age} = 5.2, *SD* = 0.8 years) completed a cricket batting task in which they aimed to hit the ball through a target zone while using either regular scaled, or modified bat and ball with an increased surface area. The number of bat-ball contacts were significantly higher when using the modified (*M* = 13.81, *SE* = 0.42) compared to the regular scaled ball (*M* = 10.65, *SE* = 0.49). Batting performance measured as shots played through target areas was also significantly higher when using the modified (*M* = 31.78, *SE* = 1.97) than the regular scaled ball (*M* = 28.85, *SE* = 2.27). More desirable technique was also observed when using the modified compared to the regular bat. Findings suggest that further modifications to regular scaled equipment can enhance skill production.

Keywords: Skill acquisition; constraints; junior sport

Introduction

Cricket, like other fast ball sports such as tennis and baseball, involves striking a moving ball with a high level of accuracy under extreme spatio-temporal constraints (Müller & Abernethy, 2012). The spatial and temporal margins for error associated with successful striking are minimal (Gray, 2002; Regan, 1997). The resultant complexity of striking actions such as cricket batting means that developing athletes may initially have difficulty acquiring the skills needed to attain success and could, potentially, become disengaged during the early stages of skill learning (Farrow & Reid, 2010). In recent years, common practice to combat this issue has been to systematically implement modified versions of sport for developing athletes (e.g., International Tennis Federation [ITF] Tennis 10s, International Basketball Federation [FIBA] Mini-Basketball), with the goal of such programmes being to enhance the success and resultant experience young performers have in their sport and increase the number of grassroots participants. Most commonly, the size of the equipment and playing area is reduced such that it is scaled to more closely mimic the playing experience of an adult performer (e.g., reductions made to racket size in tennis or court size in basketball). This approach was initially adopted based on the intuitive appeal associated with task simplification but a growing body of research now suggests that scaling results in the use of more desirable technique and higher levels of performance effectiveness (Buszard, Farrow, Reid, & Masters, 2014a; Timmerman et al., 2015).

Equipment scaling involves matching the size of the sports equipment being used to the developmental stage of the athlete (Buszard et al., 2020). When using scaled rather than full-size equipment designed for adults, junior athletes have demonstrated higher levels of performance success across a range of sports (e.g., Buszard et al., 2014a, b; Buszard, Reid, Masters & Farrow, 2016a; Elliott, Plunkett & Anderson, 2005; Larson & Guggenheimer, 2013; Rodica & Florina, 2017). Importantly, these differences are underpinned by technique more closely representing that of adult performers (Elliott et al., 2005; Isaacs, 1980; Kachel, Buszard, & Reid, 2015). Moreover, sports coaches are keen for children to have high levels of involvement when playing sports (Thomas & Wilson, 2014) and scaling appears to facilitate this through a relative increase in opportunities for action (Arias, Argudo, & Alonso, 2012; Harwood, Yeadon, & King, 2018; Fitzpatrick, Davids, & Stone, 2017).

Newell's (1986) model of constraints provides a theoretical explanation for the positive effects equipment scaling has on performance when compared to the use of full-size adult equipment in junior sport. The model suggests that skilled movement production is shaped by organismic (e.g., motivation, height), environmental (e.g., temperature, playing surface) and task constraints (e.g., equipment size, pitch size), with the performer self-organising as a function of these constraints. Equipment scaling is proposed to serve as a task constraint which facilitates the production of more functional movement behaviour and more effective performance relative to full-size adult equipment (Davids, Button, & Bennett, 2008; Renshaw, Chow, Davids, & Hammond, 2010).

Buszard et al. (2014a) investigated the effects of nine combinations of tennis rackets (small, medium and full-size; 48.3 cm, 58.4 cm and 68.6 cm long respectively) and balls (very low, low and standard compression; 25%. 75% and 100% compression respectively) on the hitting performance and technique of 6 to 8-year-old inexperienced players. The researchers used pre-defined scoring zones to assess hitting performance. Criteria based on a checklist developed by the associated governing body (e.g., racket swing, footwork) were used to assess technique. Smaller rackets and very low compression balls produced significantly better performance in comparison to bigger (medium and full-size) rackets and higher compression balls. Moreover, technical differences reported by the researchers appeared to provide evidence for the underpinning causes of the performance differences between conditions. Specifically, the very low compression ball led to more low-to-high racket swings irrespective of the racket size. Also, when using a combination of a very low compression ball and a small racket, participants stepped forward to play the shot more frequently than when using a low compression ball and a full-size adult racket (see also Buszard et al., 2014b for similar technique findings). Similarly, Buszard, Reid, Masters and Farrow (2016b) demonstrated significant improvements in performance and technique over a five-week practice period when using scaled compared with full-size tennis equipment. Buszard and colleagues suggested that the use of smaller/lighter rackets afford exploration of movement solutions that larger/heavier full-size rackets do not immediately allow.

To date, researchers investigating the effects of equipment modification on skill production have largely focused on equipment scaling that involves a reduction in the size of equipment being used. While the effects of scaling have been largely positive, some research has revealed negative effects of scaling on factors such as performance outcome (Podmenik, Leskošek, & Erčulj, 2014) and practice opportunities (Fitzpatrick et al., 2017). If the purpose of equipment modification is, indeed, to enhance engagement and increase participation levels through increased performance effectiveness and success, an important consideration is whether other modifications to scaled equipment can positively affect skill production. For example, in striking tasks with high spatial and temporal demands and minimal room for error, increasing the relative surface area of equipment used by children compared with adults could facilitate skill production and development. Potentially, when compared to regular scaled equipment which is often proportionately scaled down to match the size of equipment used by adult performers (e.g., cricket bats, tennis rackets, basketballs), and therefore decreases the surface area of the equipment in use, increasing the surface area with which to make contact could enhance performance and underlying technique further still.

Akin to ITF’s Tennis 10s and FIBA’s mini-basketball, the English Cricket Board (ECB) recently launched its All Stars initiative, which advocates the use of modified bats and balls for developing cricket players in the U5 to U8 age category. Specifically, they recommend the use of oversized tennis balls, which are more than twice the circumference of standard sized tennis balls traditionally used for junior cricket, to increase striking success when batting. In addition to the use of modified balls, modified bats are recommended. The bats are reduced in length and weight to mimic some of the constraints adult performers experience but remain the same width as full-size adult bats to increase the relative surface area allowed to junior batters. Additionally, the bats are plastic rather than wooden. Overall, these modifications make the bats wider and lighter than regular scaled wooden bats. As with the early implementation of scaled equipment, these modifications around increasing the relative surface area available to make bat-ball contact have been implemented in the absence of research supporting their effectiveness. Therefore, in this study, we compare batting performance and technique of novice junior cricket players when using modified junior cricket equipment (bats that are lighter and shorter than an adult bat but that retain the same width, and oversized balls) against regular scaled junior cricket equipment. We hypothesised that performance would be significantly better when using the modified to the regular scaled equipment because of the increased surface area of the modified equipment with which to make bat-ball contact, thus simplifying the task for participants (Renshaw et al., 2010). We also hypothesised that this enhanced performance would be underpinned by batting technique more representative of that used in the adult game.

Method

Participants

Sample size was calculated using G*Power 3.1 (Faul, Erdfelder, Land, & Buchner, 2007). We based our calculation on main effect sizes observed in previous research investigating the effect of equipment modification on performance using a similar study design (Buszard et al., 2014a). The power analysis revealed that 25 participants would be sufficient to detect a small effect size (η_p^2 = .08) with a power of 0.80 and an alpha level of .05. Forty three children (boys, n = 29 and girls, n = 14) between the ages of 4 and 7 (M_{age} = 5.2, *SD* = 0.8 years) participated in the study. This age range was chosen because the All Stars initiative is for U5 to U8 age groups. Participants in this age range therefore fit into these age groups. The children had little or no experience of playing cricket in a formalised programme. Written informed consent was provided by the children and parents/guardians in advance of testing. The study was approved by the lead author's University Ethics Committee.

Apparatus and set-up

Two types of equipment were used during the experiment; regular scaled equipment and modified equipment. The modified equipment is that used in the ECB All Stars programmes. Two different types of bat were therefore used; a regular scaled wooden size 1 Gray-Nicolls VelocityXP1 (Robertsbridge, UK) children's bat (regular bat) that was 65 cm long, 9 cm wide and weighed 0.6 kg and a modified plastic bat (modified bat) that was 65 cm long, 10.5 cm wide and weighed 0.3 kg. The two bats were therefore both scaled down in length from adult full-size bats but modified bat was wider to provide a greater surface area for bat-ball contact. Two different types of ball were also used; a regular compressed tennis ball (regular ball) that had a circumference of 20.8 cm and a modified tennis ball (modified ball) that had a circumference of 42 cm. Both balls used in the study are used within the All Stars programme. This allowed comparison between the type of ball usually used in junior cricket practice (the regular ball) and a ball with an increased surface area for making bat-ball contact (the modified ball). The modified ball was inflated to 10 psi to ensure bounce height was consistent between the two ball types and, as such, any observed differences could be attributed to the surface area of the balls rather than the bounce height. The bounce height of the balls was recorded from a 1 m drop on the surface used for the testing protocol and measured using Kinovea software. Each ball was bounced four times. A Mann-Whitney U test showed no significant difference in bounce height between the modified ball (M = 53.64cm, SD = 1.46) and the regular ball (M = 54.82cm, SD = 0.89), U = 4.00, p = .34).

Testing took place on a flat tarmacked surface which provided a consistent ball bounce. The participants batted 4.7 m away from the researchers who threw underarm to a 0.6 m by 0.4 m landing area 0.6 m in front of the participants. Appropriate distances were identified through pilot testing. Scoring zones were created using markers placed laterally 4.7 m from the participant. The straightest shots scored 5 points, with wider shots scoring 4, 3 or 2 points and if the participant made bat-ball contact but it did not go through the scoring area, they scored 1 point. No points were awarded if contact was not made with the ball. The straightest area was deemed to be awarded the greatest score because it was perpendicular to the landing area and it is normally the area where there are fewest fielders in a game of cricket. The video cameras (Panasonic HC-V720 HD Camcorder, Berkshire, UK) were positioned behind and side-on to capture performance and technique footage, respectively, used for later analysis (see Figure 1).

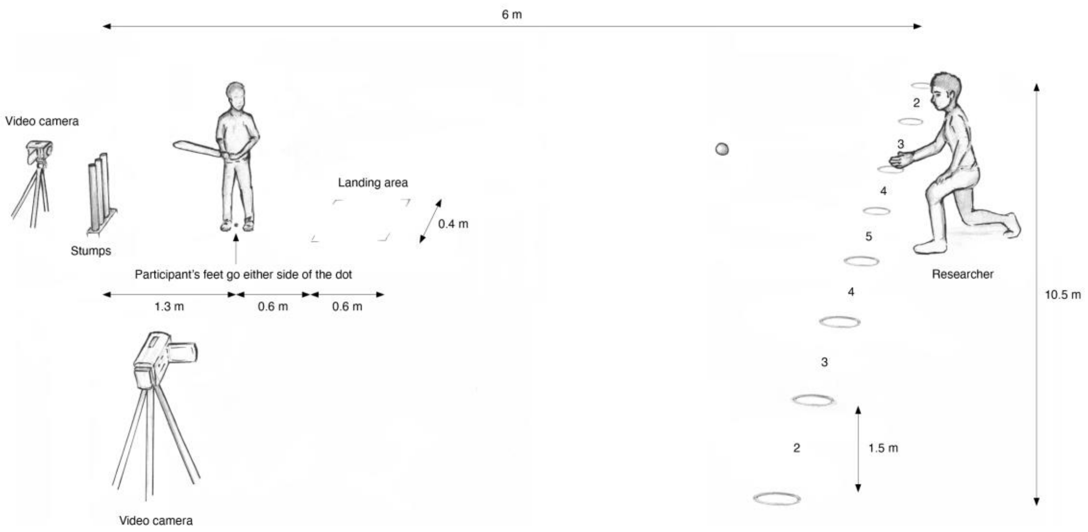

Figure 1. Testing set-up.

Procedure

Each participant performed 20 trials in four conditions (the number of trials per condition was therefore greater than that used in related research, e.g., Buszard et al., 2014a, b; Elliott et al., 2005). The four conditions were: modified bat/modified ball, regular bat/modified ball, modified bat/regular ball and regular bat/regular ball. A Latin square design (as used by Buszard et al., 2014a) ensured a counterbalanced order for the completion of conditions. The number of ball feeds was evenly split across the two researchers during testing.

The researchers fed underarm throws to the participants to hit through the scoring zone. If the ball did not bounce in the landing area outlined in Figure 1, the trial was repeated. 4.72% of trials were therefore repeated. The participants were instructed to hit the ball through the performance scoring zone to score as many points as possible. To maximise accuracy, the performance score was analysed post-test via video recording. The only other instruction given to the participants was to begin by positioning their feet either side of the dot in front of them so they did not artificially shorten or lengthen the feed. Due to the age of the participants they were given frequent praise to maintain their motivation throughout each set of trials. Following each set of 20 trials, participants had approximately five minutes break to allow time for other participants to complete their trials and prevent fatigue/boredom. Upon having batted with each bat/ball combination, participants were asked to identify the bat and ball they preferred using during the experiment. This was done to ascertain whether any performance differences would be reflected in equipment preferences (Buszard et al., 2014a; Regimbal, Deller, & Plimpton, 1992).

To check for consistency of feed between conditions and researchers, ten participants' trials were randomly sampled from the group (five from each researcher). All of the ten participants' trials were analysed yielding a total of 200 trials per condition and 400 trials per researcher. A frame-by-frame analysis was conducted to calculate the average ball flight time for each researcher in each condition (the time taken for the ball to travel from the researchers' hand until contact with the ground on the bounce). Differences in ball flight across conditions were negligible (modified bat/modified ball: $M = 0.53$ s, $SD = 0.04$; modified bat/regular ball: $M = 0.52$ s, $SD = 0.04$; regular bat/modified bat: $M = 0.52$ s, $SD = 0.04$; regular bat/regular ball: $M = 0.53$ s, $SD = 0.04$), as were ball flight times between researchers (modified ball thrown by researcher 1: $M = 0.51$ s, $SD = 0.03$; researcher 2: $M = 0.55$ s, $SD = 0.04$; regular ball thrown by researcher 1: $M = 0.52$ s, $SD = 0.04$; researcher 2: $M = 0.55$ s, $SD = 0.03$).

Two weeks later, nine participants were re-tested across each condition to measure test-re-test reliability. Intraclass correlation coefficients for performance scores showed moderate to high reliability across the 4 conditions, with regular bat/modified ball and modified bat/regular ball conditions producing high ICC values of .82 and .85 respectively and modified bat/modified ball and regular bat/regular ball conditions producing moderate ICC values of .63 and .69 respectively.

A technical analysis was conducted using video footage from the side-on camera. Participants were not told that their technique was being analysed so they did not attempt to artificially alter their skill execution. The criteria for the technical analysis was developed by two ECB Level 2 qualified coaches with a combined experience of 15 years coaching this specific age range. The following technical points were analysed for each trial in each condition: (1) grip distance: hands were close together on the handle; (2) back swing: the hands on the bat had a backwards motion that went to the back hip or beyond, (3) follow through: the hands on the grip went beyond the front hip; (4) foot step forward: front foot moved towards the bounce of the ball from the original pre-shot stance position. A score of 1 was given if the criteria were met and 0 if not. The two coaches first watched a sample of 100 trials together to establish agreement on instances where criteria were met prior to one of the coaches analysing all of the data.

Data Analysis

First, to determine whether the frequency with which participants made contact with the ball was dependent on the equipment used, we conducted a 2 (Bat [modified, regular]) × 2 (Ball [modified, regular]) repeated measures Analysis of Variance (ANOVA). Next to determine whether differences in batting performance (number of points scored) emerged as a result of the combination of bat and ball being used, we conducted a further 2 (Bat) × 2 (Ball) repeated measures ANOVA. A 2 (Bat) × 2 (Ball) Multivariate Analysis of Variance (MANOVA) with repeated measures was conducted to determine any differences in technique arising from the combination of bat and ball being used, with grip distance, backswing, follow through and step forward acting as dependent variables. Finally, to determine participants' preference for each type of bat and ball used, percentages were calculated to reflect the proportion of participants who expressed preference for that specific piece of equipment. Significant interactions were followed up by pairwise comparisons and the alpha level was set at .05. Effect size was reported with partial eta squared (η_p^2) and Cohen's *d* values. Wilks' Lambda values are reported for multivariate outputs while Greenhouse-Geisser corrections were employed to account for any violations of sphericity. Finally, sequential Bonferroni adjustments were used in cases involving multiple comparisons.

Results

Hit Frequency

Mean (and standard error) number of bat-ball contacts made in each condition are presented in Figure 2. The repeated measures ANOVA revealed a significant main effect of Ball condition on hit frequency, $F(1, 43) = 54.35$, $p < .01$, $\eta_p^2 = .56$. The frequency of successful bat-ball contacts was significantly higher when using the modified ($M = 69.03\%$, $SE = 1.79$) compared with the regular ball ($M = 53.24\%$, $SE = 2.15$). Neither the main effect of Bat, $F(1, 43) = .00$, $p = .96$, $\eta_p^2 = .00$, nor the Bat × Ball interaction were significant, $F(1, 43) = 2.59$, $p = .12$, $\eta_p^2 = .06$.

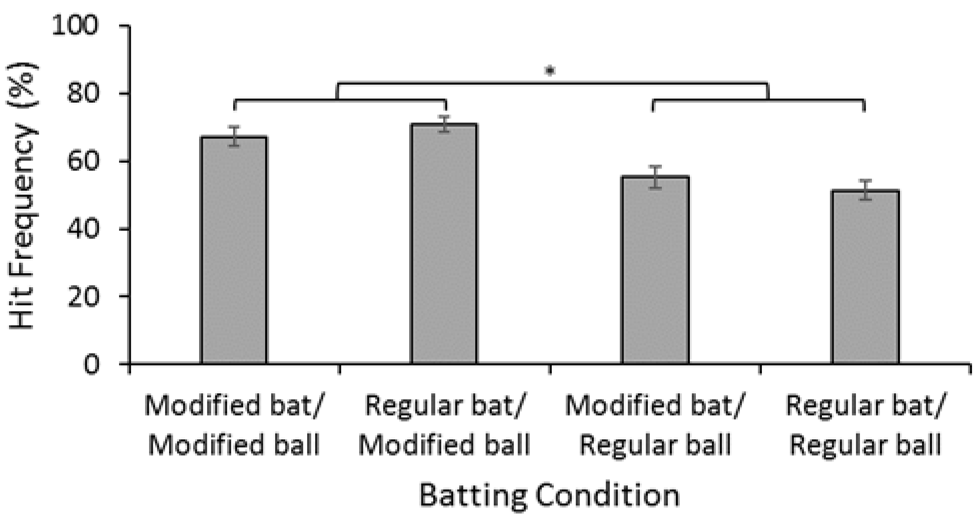

Figure 2. Mean (SE) hit frequency percentage scores for each of the batting conditions. * $p <$ .05.

Hitting Performance

Mean (and standard error) performance scores in each condition are presented in Figure 3. ANOVA revealed a significant main effect of Ball, $F(1, 43) = 5.25$, $p = .03$, $\eta_p^2 = .11$, with significantly higher performance scores being observed when using the modified ball ($M = 31.78$, $SE = 1.97$) compared to the regular ball ($M = 28.85$, $SE = 2.27$). The main effect of Bat was not significant, $F(1, 43) = .08$, $p = .79$, $\eta_p^2 = .00$. However, a significant Bat × Ball interaction was observed, $F(1, 43) = 4.49$, $p = .04$, $\eta_p^2 = .10$. Pairwise comparisons revealed that, when using the modified bat, no differences in performance scores were observed between ball conditions, $t(43) = .06$, $p = .95$, $d = 0.01$. However, when using the regular bat, performance scores were significantly higher when using the modified compared to the regular ball, $t(43) = 3.06$, $p < .01$, $d = 0.40$. No significant differences were observed between bat conditions when using the modified ball, $t(43) = 1.68$, $p = .10$, $d = 0.21$, or the regular ball, $t(43) = 1.20$, $p = .24$, $d = 0.16$.

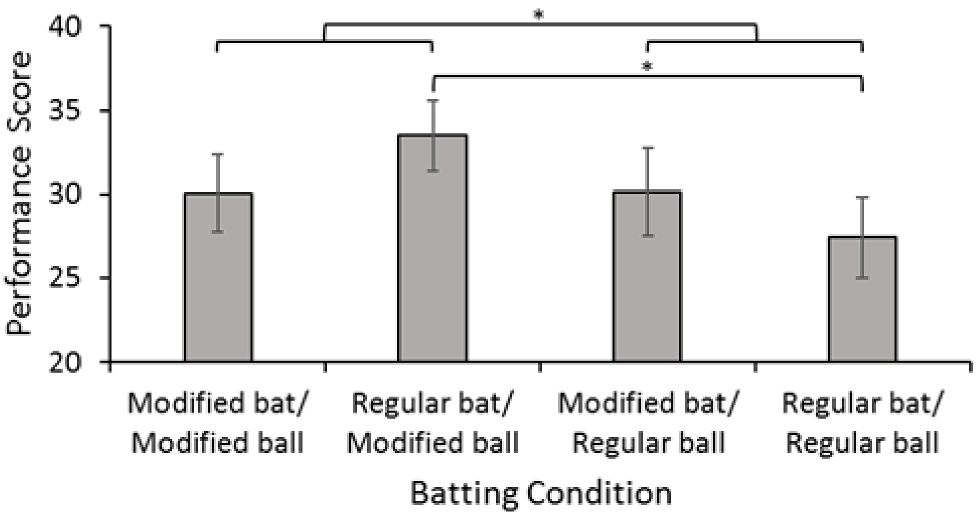

Figure 3. Mean (SE) performance scores for each of the batting conditions. * $p < .05$.

Technique

MANOVA revealed that the main effect of Ball, Wilks' Lambda = .96, $F(4, 40) = .39$, $p = .81$, $\eta_p^2 = .04$, was not significant. However, a significant main effect of Bat was observed, Wilks' Lambda = .46, $F(4, 40) = 11.58$, $p < .01$, $\eta_p^2 = .54$. The univariate output revealed main effects of bat type on grip distance, $F(1, 43) = 26.95$, $p < .01$, $\eta_p^2 = .39$, and backswing technique, $F(1, 43) = 6.39$, $p = .02$, $\eta_p^2 = .13$. The number of occasions on which participants displayed effective grip distance technique was higher in the modified (M = 12.42, SE = 1.14) compared to the regular bat conditions (M = 6.83, SE = 1.08). Similarly, participants performed an effective backswing more often in modified (M = 8.03, SE = 1.17) compared to regular bat conditions (M = 6.89, SE = 1.10). Finally, the Bat × Ball interaction was not significant, Wilks' Lambda = .82, $F(4, 40) = 2.23$, $p = .08$, $\eta_p^2 = .18$.

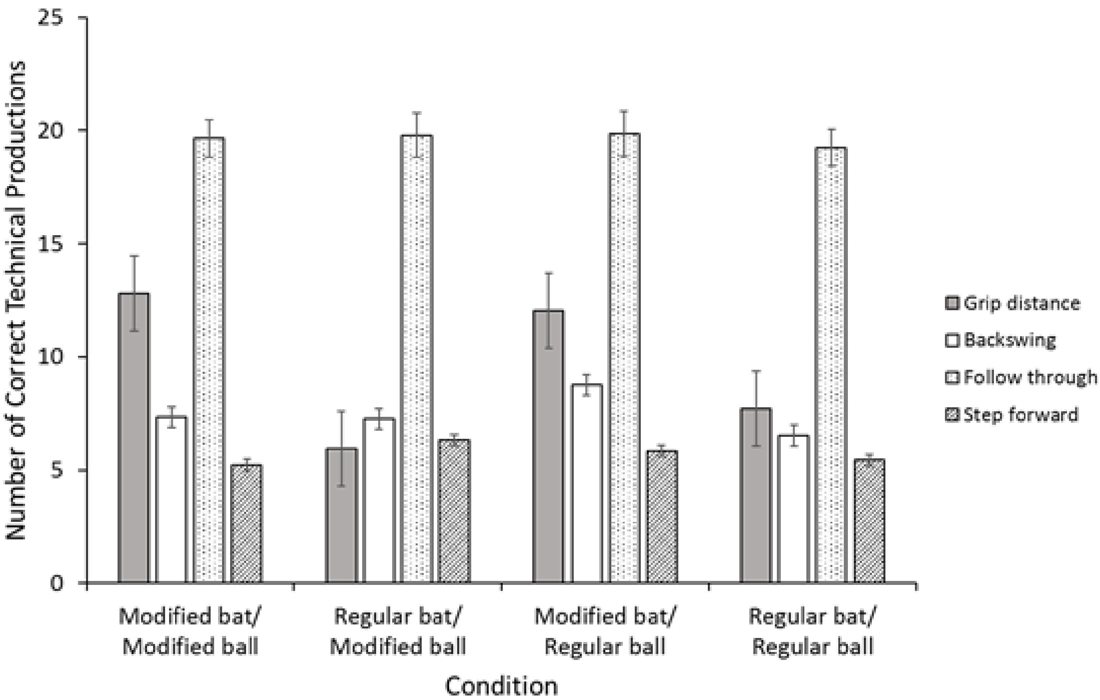

Figure 4. Mean (SE) technique scores for each of the technical variables across batting conditions.

Equipment Preference

Participants preferred using the modified ball (70.70%) over the regular ball (29.30%), but very little difference was observed between preference for the modified (51.20%) or regular bat (48.80%).

Discussion

This aim of the study was to investigate the effect of modified junior cricket equipment on batting performance and technique compared with regular scaled junior cricket equipment. The modified ball was increased in size to provide a greater surface area for bat-ball contact compared to the ball commonly used in junior cricket. Both the modified bat and the regular scaled bat were reduced in size compared to adult full size equipment, yet the modified bat retained the same width as a full-size bat to increase surface area for contact, as well as being lighter than the regular scaled bat. Given that task simplification has been shown to yield higher levels of performance and more desirable technique (Buszard et al., 2016a; Renshaw et al., 2010), we hypothesised that batting performance and technique would be significantly better when using modified compared with regular scaled equipment.

Our hypothesis that participants would perform better in modified than regular scaled conditions was partially supported. Hit frequency and performance scores were significantly higher when using the modified compared with the regular ball but no such differences were observed between bat conditions. Modified balls have previously been shown to positively influence performance of young children in other sports. For example, slightly larger, low compression tennis balls elicit higher performance levels in tennis (Buszard et al., 2014a; Farrow & Reid, 2010; Larson & Guggenheimer, 2013). Buszard et al. (2014a) suggested that the reduced compression of these balls provides a more favourable bounce compared to regular balls which provide less time to make racket-ball contact. Similarly, in this study, the modified ball allowed participants to hit more balls to the target area. In contrast with previous studies, because ball compression and bounce height were controlled in the current study, the size of the ball appears to be the determining factor. The larger circumference of the modified ball provided greater chance of bat-ball contact, as evidenced by the higher hit frequency scores. It may also have made it easier to track, facilitating higher success levels. Young children (seven to eight-year-olds) have been shown to have weaker interceptive striking skills in comparison to older children (15 to 16-year-olds) (Rothenberg-Cunningham & Newell, 2013), and early catching research found four to six-year-olds caught larger balls more frequently than smaller balls (Payne, 1982). In the current study, using a larger ball that may be easier to track and intercept positively impacted children’s batting performance.

Given the success participants had with the modified ball, it is not surprising that 70% of them preferred using it over the regular ball. In addition to the aforementioned performance benefits, there may also be psychological benefits to equipment modifications yielding larger surface areas. If children are not frequently making bat-ball contact, and experiencing some degree of performance success, this may detrimentally affect their self-efficacy and motivation to continue with the sport (Arias, 2012; Chase, Ewing, Lirgg, & George, 1994). With positive correlations shown between perceptions of motor coordination skill and continued physical activity (Southall, Okely, & Steele, 2004; Stodden et al., 2008), the use of modified equipment could be a powerful intervention to develop perceptions of skill success. Coaches and national governing bodies should therefore consider the role modified equipment plays in the success experienced by those in their formative years.

We further hypothesised that more effective batting performance would be underpinned by more desirable technique. Two of the four technical aspects were significantly better when using the modified compared to the regular scaled bat. When using the heavier, regular scaled bat, participants displayed a more limited backswing and a grip with the hands further apart. A more limited backswing restricts the amount of force the batter can generate to hit the ball (Sarpeshkar & Mann, 2011), thereby reducing the chances of scoring runs and lowering success. Given that bat-ball contact frequency was not affected by the type of bat used, we suggest that these technical differences could be attributed to the weight of the bat rather than the surface area. Findings are comparable to Buszard et al. (2014a) who observed more proficient movement with scaled (smaller, lighter racket) compared to full-size equipment (larger, heavier racket). Accumulating evidence therefore indicates that the equipment used at a formative age has a clear effect on the technique children employ during skill production. Ironically, the use of more ‘adult-like’ equipment appears to reduce the child’s chances of performing the skill with an ‘adult-like’ technique.

Returning to the performance data, the bat × ball interaction is an interesting finding. The modified bat appears to have been easier to manipulate than the regular bat (as evidenced by more desirable grip and backswing technique), allowing players to make effective bat-ball contact regardless of ball condition. In contrast, performance effectiveness with the regular bat depended on the ball being used. When combined with the regular ball, performance with the regular bat was relatively poor. This is likely due to a combination of the bat being difficult to manipulate and the small surface area of the equipment being used. However, when combined with the modified ball which increases the surface area available for bat-ball contact, and thus makes the task easier, batting performance was greatly enhanced compared when the regular ball was used. Relating this to Newell's (1986) model of constraints, this finding highlights the profound effect the manipulation of a single constraint can have on the reorganization of the movement system. Moreover, these data suggest that, rather than an all-or-nothing approach to equipment modification being adopted, specific combinations of task constraints may yield the most effective behaviours.

We nevertheless only tentatively highlight the higher performance scores when combining the regular bat with the modified ball and note that these scores do not necessarily imply a combination of task constraints that will yield effective skill learning. Specifically, participants held the bat with a wider grip and did not perform a full backswing as frequently when using the regular bat. Given that the task was to strike the ball through a relatively close target area that was kept constant throughout, there was little need for participants to display adaptability or flexibility in the movement solutions they produced. The restricted swing employed when using the regular scaled bat therefore may actually have been of benefit when combined with the modified, larger ball. Freezing mechanical degrees of freedom and reducing movement variability to control movements with some degree of effectiveness is a common characteristic of early learning (Bernstein, 1967). In contrast, skilled performance is characterised by consistency in the movement of the end effector itself but with a higher level of functional variability in the body parts contributing to movement production. Buszard et al. (2020) recently demonstrated that scaled equipment yields higher levels of functional variability in junior tennis players compared with full-size adult equipment (Buszard et al., 2020). While movement variability has not been investigated in this study, we tentatively suggest that the lighter modified bat may have led to a greater range of movement than the heavier regular scaled bat in this study. From a technical development perspective, conditions that promote greater exploitation of mechanical degrees of freedom characterise a more advanced stage of learning which are likely to be most effective.

Our findings appear to suggest independent beneficial effects of different equipment modifications. Specifically, increasing the size/surface area of the ball being struck appears to have a positive effect on the frequency with which bat-ball contact can be made and overall performance success while modifying the weight of the bat leads to more desirable technique. While coaches should therefore consider how modifications to different types of equipment may be beneficial at different stages and for different aspects of a child's development, the combination of higher levels of success and more desirable technique when using modified equipment would appear to yield an environment that could facilitate both motivation for continued participation and effective skill development (Arias, 2012; Buszard et al., 2016b).

The study is not without limitations. The testing set-up may not have been challenging enough to effectively demonstrate the impact of bat type on performance outcome. Participants scored a similar number of points whether they were using the modified or regular scaled bat. The scoring zone distance therefore seems to have been close enough for participants to do so whether they used a more functional technique or not. Additionally, our approach to assessing the effectiveness of the equipment was limited to performance outcome (points scored through a central area). Researchers have suggested that modified equipment may promote exploration of movement solutions (Buszard et al., 2016a; Fitzpatrick et al., 2017), a process considered of great importance to skill learning. In future, we therefore recommend that researchers include a related measure in their study designs. Representative tasks that mimic the demands of competition more fully than the current task would be particularly suited to this as variability in shots attempted could be recorded without any artificial manipulation of rules or scoring zones. Moreover the use of more representative tasks with higher levels of functionality (e.g., through the presence of fielders for example) would allow the effectiveness of the modifications employed in the current study to be more fully understood (Connor, Farrow, & Renshaw, 2018; Pinder, Davids, Renshaw, & Araujo, 2011).

Most research on equipment scaling has focused on reducing the size of equipment used to match the athlete's developmental stage. Our findings highlight that, modifications that further simplify the task can positively affect performance and technique. Specifically, modifying the surface area and weight of equipment can lead to higher levels of success and the production of more desirable technique for players in their formative years. Further research should be conducted to enhance understanding of how such modifications impact factors such as engagement, movement variability and performance in representative settings. Our findings highlight the multidimensional nature of practice design, with modification of different types of equipment yielding different effects. Coaches should bear these findings in mind when designing practice for young athletes.

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