Muscular strength, fitness and anthropometry in elite junior basketball players

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STUDENT DECLARATION

"I, Eric Drinkwater, declare that the PhD thesis entitled *Muscular strength, fitness and anthropometry in elite junior basketball players* is no more than 100,000 words in length, exclusive of tables, figures, appendices, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work."

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Eric Drinkwater

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THESIS ABSTRACT

Basketball is a sport with many complex demands that require a combination of fitness, skills, team tactics and strategies, and motivational aspects. However key areas that are likely to play an important role in a basketball player's success are muscular strength, fitness and body size. Methods of evaluating and developing these characteristics have been extensively tested in controlled research settings, but there is a dearth of research exploring the value of, and methods of improving, muscular strength, fitness and body size of basketball players within the demanding schedule of an elite junior development program. These were therefore explored in this thesis.

Study 1 Concerns about the value of physical testing and apparently declining test performance in junior basketball players prompted a retrospective study of trends in anthropometric and fitness test scores related to recruitment age and recruitment year. Players were 1011 females and 1087 males entering Basketball Australia's State and National programs (1862 and 236 players respectively). Players were tested on 2.6 ± 2.0 (mean ± SD) occasions over 0.8 ± 1.0 y. Test scores were adjusted to recruitment age (14-19 y) and recruitment year (1996-2003) using mixed modeling. Effects were estimated by log transformation and expressed as standardized (Cohen) differences in means. National players scored more favorably than State players on all tests, differences being generally small (standardized differences, 0.2 – 0.6) or moderate (0.6 – 1.2). On all tests, males scored more favorably than females, with large standardized differences (>1.2). Athletes entering at age 16 performed at least moderately better than athletes at 14 y on most tests (standardized differences, 0.7 - 2.1), but test scores often plateaued, or began to deteriorate when entering at ~17 y. Some fitness scores deteriorated over the 8-y period (1996-2003), most notably a moderate increase in sprint time and moderate (National male) to large (National

female) declines in shuttle-run performance. Variation in test scores between National players was generally less than that between State players (ratio of SD, 0.83 - 1.18). More favorable means and lower variability in higher-level athletes highlights the potential utility of these tests in junior basketball programs, though secular declines in fitness should be a major concern for Australian basketball coaches.

Study 2 These findings prompted further investigation into the magnitude of changes in individual player fitness and anthropometric test scores between phases of a year and over multiple years. Detailed information on the direction and magnitude of training-induced changes in fitness in a within-subject design is essential for basketball coaches to evaluate and prescribe conditioning programs. Mixed modeling was used to estimate mean changes within and between seasons, and to estimate individual variability as the standard deviation of change scores between assessments. Changes were expressed as standardized (Cohen) effect sizes for interpretation of magnitudes (trivial <0.2; small 0.2-0.6, moderate 0.6-1.2). In the first 2 y National and State males showed small longitudinal improvements in body mass, skinfolds, and shuttle-run performance (effect size 0.28 – 0.42). After 2 y National females made small improvements in most tests (0.27 – 0.42), but National males showed a small decline in shuttle-run performance (0.55). Other changes in mean test scores within and between seasons were trivial. Individuals showed small to moderate variability about the mean change between phases (0.23 – 0.87) and between years (0.26 – 1.03), with State-level players having greater variation in all tests (State/National ratio 1.1 – 2.4). Coaches or sport scientists monitoring or modifying fitness of basketball players should recognize there is generally little overall change in mean fitness within and between seasons. They should also take into account the small to moderate changes in individuals. While fitness training programs for athletes with dedicated needs are

relatively well supported in the literature, there is very limited peer-reviewed literature to assist the resistance training coach in developing body size, strength, and power of team-sport athletes.

Study 3 Most high-level basketball players participate in an organised resistance training program to improve muscular strength, fitness, and body size. Bench press is one of the most commonly performed resistance training exercises, and there are many different training philosophies revolving around manipulation of different components of the bench press mechanics. During the concentric movement of the bench press, there is an initial high-power push after chest contact, immediately followed by a characteristic area of low power, the so-called “sticking region”. During high-intensity lifting, this decline in power can result in a failed lift attempt. The purpose of this study was firstly to determine the validity of an optical encoder to measure power, and secondly to employ this device to determine power changes during the initial acceleration and “sticking region” during fatiguing repeated bench presses. Twelve highly trained junior basketball players performed a free-weight bench press, a Smith Machine back squat, and a Smith Machine 40 kg bench press throw for power validation measures. All barbell movements were simultaneously monitored using videography and an optical encoder. Eccentric and concentric mean and peak power were calculated using time and position data derived from each method. Validity of power measures between the video (criterion) and optical encoder scores were evaluated by standard error of the estimate (SEE) and coefficient of variation (CV). Seven subjects then performed four sets of six bench press repetitions progressively increasing from 85 to 95% of their 6 repetition maximum, with each repetition continually monitored by an optical encoder. The power SEE ranged from 3.6 to 14.4 W (CV, 1.0-3.0%; correlation, 0.97-1.00). During the bench press training,

peak power declined by ~50% ($p<0.05$) during the initial acceleration phase of the final two repetitions of the final set. While decreases in peak power of the sticking point were significant ($p<0.05$) as early as repetition six (-42%) they reached critically low levels in the final two repetitions (~ -95%). In conclusion, the optical encoder provided valid measures of kinetics during free-weight resistance training movements. The decline in power during the initial acceleration phase appears a factor in a failed lift attempt in the sticking point in highly trained junior basketball players.

Study 4 The power loss in the first phase of the bench press only becomes a limiting factor when the loss of power in the sticking point leads to lift failure. Therefore, training to the point of failure may be an important stimulus for generating sufficient power in the first phase of the bench press to successfully press through the sticking point. This study investigated the importance of training leading to repetition failure in optimising the performance of elite junior athletes in two different tests: six-repetition maximum (6RM) bench press strength and 40kg bench throw power. Subjects were 26 elite junior male basketball (n=12, age 18.6 ± 0.3 y, height 202.0 ± 11.6 cm, mass 97.0 ± 12.9 kg) and soccer (n=14, age 17.4 ± 0.5 y, height 179.0 ± 7.0 cm, mass 75.0 ± 7.1 kg) players with a history of greater than six months strength training. Subjects were initially tested twice for 6RM bench press mass and 40kg Smith Machine bench throw power output (W) to establish retest reliability. Subjects then undertook bench press training three sessions per week for six weeks, using equal volume programs (24 total repetitions x 80-105% 6RM in 13 min 20 s). Subjects were assigned to one of two experimental groups designed to either elicit repetition failure with four sets of six repetitions every 260 s (RF_{4x6}) or allow all repetitions to be completed with eight sets of three repetitions every 113 s (NF_{8x3}). The RF_{4x6} treatment elicited substantial increases in strength (7.3 ± 2.4kg, +9.5%,

$p<0.001$) and power (40.8 ± 24.1 W, +10.6%, $p<0.001$), while the NF_{8x3} group elicited 3.6 ± 3.0kg (+5.0%, $p<0.005$) and 25 ±19.0 W increases (+6.8%, $p<0.001$). The improvements in the RF_{4x6} group were significantly greater than the repetition rest group for both strength ($p<0.01$) and power ($p<0.05$). Bench press training that leads to repetition failure induces greater strength gains than non-failure training in the bench press exercise for elite junior team sport athletes.

Study 5 Strength improvements are greater when resistance training continues to the point where the individual cannot perform additional repetitions (i.e. repetition failure). Performing additional forced repetitions after the point of repetition failure to further increase the set volume is a common resistance training practice. However, whether increasing the number of forced repetitions increases the magnitude of strength development is unknown and was investigated here. Twenty two team-sport athletes trained for six weeks completing either 4x6, 8x3, or 12x3 (sets x repetitions) of bench press. The 4x6 and 12x3 protocols increased the number of forced repetitions by respectively increasing work intervals or volume compared to the 8x3 group. Subjects were tested on 3- and 6-repetition maximum (RM) bench press (81.7±9.9 and 76.2±9.2 kg respectively, mean ±SD), and 40kg Smith Machine bench press throw power (756±156 W). The 4x6 and 12x3 groups had more forced repetitions per session ($p<0.01$) than the 8x3 group (4.4±0.9 and 3.6±0.8, and 2.0±0.5 repetitions). As expected, all groups improved 3RM (4.6 kg, 95% Confidence Limits: 3.2-6.1), 6RM (4.9 kg, 3.3-6.5), bench throw peak power (59 W, 23-95), and mean power (23 W, 4-42) (all $p<0.01$). There were no significant differences in strength or power gains between groups. In conclusion, when repetition failure was reached, neither additional forced repetitions, nor additional set volume further improved the

magnitude of strength gains. This finding questions the efficacy of these current common strength training practices.

Conclusions The quality of key fitness and anthropometric test scores of Australian junior basketball players showed evidence of decline over a 7 yr study period despite the importance of fitness and body composition to basketball. Fortunately, there is sufficient individual variation in changes in fitness and anthropometry test scores to indicate that substantial improvements are possible with an appropriate training program. As a method of improving fitness, the bench-press resistance training model, consisting of two separate six-week training programs equal in volume and training time but differing in the amount of fatigue, showed that training to the point of repetition failure elicited greater strength adaptations than non-failure training. Refinement of the training protocol allowed further comparison of the effects of additional training volume and a greater number of forced repetitions. Taken together these experimental findings support the notion that training to the point of repetition failure is an important component of a periodized training program for strength development. However six weeks of training using forced repetitions with the assistance of a spotter conveyed no further benefit to strength, power, or hypertrophic adaptations. Additional research is required to verify whether the transfer of these upper body adaptations apply to lower-body activities such as squats, and whether high intensity short term strength and conditioning programs can improve power output enough to have a substantial positive impact on basketball-specific skills such as running and jumping.