Concerns about the value of physical testing and apparently declining test performance in junior basketball players prompted this retrospective study of trends in anthropometric and fitness test scores related to recruitment age and recruitment year. The participants were 1011 females and 1087 males entering Basketball Australia's State and National programmes (1862 and 236 players, respectively). Players were tested on 2.6 +/- 2.0 (mean +/- s) occasions over 0.8 +/- 1.0 year. Test scores were adjusted to recruitment age (14-19 years) and recruitment year (1996-2003) using mixed modelling. Effects were estimated by log transformation and expressed as standardized (Cohen) differences in means. National players scored more favourably than State players on all tests, with the differences being generally small (standardized differences, 0.2-0.6) or moderate (0.6-1.2). On all tests, males scored more favourably than females, with large standardized differences (&gt;1.2). Athletes entering at age 16 performed at least moderately better than athletes entering at age 14 on most tests (standardized differences, 0.7-2.1), but test scores often plateaued or began to deteriorate at around 17 years. Some fitness scores deteriorated over the 8-year period, 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 standard deviations, 0.83-1.18). More favourable means and lower variability in athletes of a higher standard highlight the potential utility of these tests in junior basketball programmes, although secular declines should be a major concern of Australian basketball coaches.
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We also acknowledge the efforts of ITC and AIS coaches and athletes for their commitment to the testing program.
Title: Modelling age and secular differences in fitness between junior basketball players

Keywords: anthropometry, athlete, adolescent, fitness
Abstract
Concerns about the value of physical testing and apparently declining test performance in junior basketball players prompted this 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 modelling. 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 at ~17 y. Some fitness scores deteriorated over the 8-y period, 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 should be a major concern of Australian basketball coaches.
Introduction

Several anthropometric and fitness tests, common to basketball programs throughout Australia (Stapff, 2000), are often used by coaches in recruiting new players into State and National programs. Despite previous studies in basketball linking anthropometric and fitness test scores with level of play (McKenzie, 1985), player success (Angyan et al., 2003; Hoare, 2000), playing time (Hoffman et al., 1996), position (Latin et al., 1994), and team success (Groves and Gayle, 1993), the information available for coaches is limited to basic descriptive statistics collected on small samples of basketball players (Ackland et al., 1997; Bale, 1991; Hoffman et al., 1991). While some studies go beyond one year (Hunter et al., 1993; Lamonte et al., 1999) and have greater than 100 athletes (Berg and Latin, 1995; Kellis et al., 1999; Latin et al., 1994) they are limited in their practical application and statistical power. Interpreting results from studies using large numbers of players in different locations is often difficult due to differences in test protocols (Latin et al., 1994). One recent study (Drinkwater et al., 2005) has investigated changes in fitness of Australian basketball players addressing changes within player fitness over time in the training program, but does not address trends in the fitness level of newly recruited players each year. Development of detailed reference values for test scores for players of different age groups, genders, and competitive levels are required to allow coaches to set appropriate fitness goals for specific groups of junior basketball players.

Although fitness improves through the adolescent years (Rowland, 1996), there is a trend in recent decades towards declining fitness in Australian school children (Tomkinson et al., 2003). This latter trend is generating concern in the public health and sporting communities. There has been no exploration of how trends in the general
population compare to the fitness levels of adolescents recruited into high-level sporting programs, although anecdotal reports from coaches suggests a trend of declining fitness in junior Australian basketball. Of particular interest are the secular trends of anthropometric and fitness test scores in the recruitment of new players to the State and National levels. Examination of secular trends would prove valuable information for coaches and administrators to help them clarify whether fitness trends in the general population are affecting fitness levels of basketball players entering elite programs, assess the value of prior recruitment patterns, identify important anthropometric and fitness factors in recruitment for elite programs, and enhance the physical preparation of players at junior levels.

Team sports typically encompass a wide variety of anthropometric and fitness characteristics in order for players to play different positions in the game, and basketball is no exception (Trninic and Dizdar, 2000). While some variation between athletes is expected, establishing reference ranges for between-athlete variation in both anthropometric and fitness test results would allow coaches to identify exceptional results for talent identification purposes and assign remedial fitness training and goal setting. The aims of this study were to determine the effects of age, gender and competitive level on anthropometric and fitness test scores in junior basketball players, and identify secular differences in newly recruited players over an eight-year period.
**Methods**

**Subjects**

The sample comprised 1011 females (904 State players, 107 National players) and 1087 males (958 State players, 129 National players) entering Basketball Australia (BA) State and National training programs. Athlete test scores were obtained during regularly scheduled fitness testing in between 1996 and 2003 inclusive. Individual athletes were tested 2.6 ± 2.0 (mean ± SD, minimum: 1, maximum: 14) occasions over 0.8 ± 1.0 y. The age of the four groups were: National males 17.1 ± 1.0 y (range: 15-19), National females 16.7 ± 1.2 y (14-19), State males 15.7 ± 0.9 y (13-20) and State females 15.5 ± 0.9 y (13-21). Subjects (or parent/legal guardian) provided written informed consent for testing, training, data collection, and publication of results as part of their Scholarship Agreement with the Australian Institute of Sport (AIS) and/or BA Intensive Training Centre (ITC) programs.

**Experimental Design**

Junior sport typically functions in a tiered system where the better players at a particular level graduate to the next higher level, moving from local competitions to State, and eventually National teams. All National subjects participated at National Under-16 and Under-18 Men’s and Women’s Australian Junior Camps, and/or were on full-time scholarships with the AIS Men’s and Women’s Basketball teams. State players trained at one of seven State or Territory ITC Programs around Australia. Tests were conducted in accordance with test protocols prescribed by the national sporting body (Stapff, 2000). Testing group sizes ranged from 5 to 70 athletes but were typically 10-14 players, approximating the size of a basketball team. All results
were compiled from the records of routine fitness testing conducted on players at each state ITC, at the Australian Junior Camps, and the AIS.

Description of Tests

Anthropometric Measurements
Athlete stretched height and body mass were measured using a stadiometer and digital scales respectively. Typical error of measurement (TEM) (Hopkins, 2000) for measuring both height and body mass, including biological variation, is typically not more than 1% (Norton et al., 1996). Skinfolds measurements comprised the sum of seven skinfold thicknesses from triceps, subscapular, biceps, supraspinale, abdominal, front thigh, and medial calf measured with a TEM typically <3% for intertester variability (Norton et al., 1996).

Fitness Tests
Two maximal effort tests were used to measure leg power: 20-m sprint and vertical jump (Stapff, 2000). The fastest of three attempts of elapsed movement time from a stationary standing start to a 20-m point was recorded using electronic light gates (SWIFT Performance Equipment, Lismore, Australia). A vertical jump test measured the best of three maximal counter-movement jump heights allowing a single backward step using a YardStick vertical jump apparatus (SWIFT Performance Equipment, Lismore, Australia). The aerobic fitness test involved repeatedly running back and forth a 20-m straight line at a progressively faster pace set by a recorded tone until the athlete could no longer run in rhythm with the tone, a test that has been previously demonstrated to have a high correlation with $\text{VO}_{2\text{max}}$ (Ramsbottom et al., 1988).
Athletes had performed these tests many times prior to testing at State- and National-levels so we assumed a minimal learning effect for our results.

**Fitness Test Reliability**

To isolate biological and technical error in the measurement from physiological adaptations to training the TEM was established with a series of test re-test reliability trials (Hopkins, 2000). A subgroup of 12 male and 12 female National level players completed duplicate tests within 5-7 days under standardized conditions prior to analyzing the annual fitness testing data.

**Statistical Analyses**

Log transformation and repeated-measures mixed linear modelling using Proc Mixed in the Statistical Analysis System software (Version 8.1, SAS Institute, Cary, North Carolina, USA) provided estimates of percent differences in means (fixed effects) and between- and within-athlete coefficients of variation (CV) (random effects) for each fitness and anthropometric test. Separate analyses were performed for each gender at each level (i.e. State Female, National Female, State Male, and National Male).

The fixed effects in each analysis were Year, Year*Year, Age, and Age*Age, where Year was a numeric between-subject effect representing the calendar year when each player was recruited (1996 - 2003), and Age was a numeric between-subject effect representing the age of the player at recruitment (14 – 19 y). Quadratic effects for Age, and Year were included in the model as the simplest approach to allow for non-linear effects of these predictors.
The random effects in the analyses were Athlete and the residual, where Athlete was the identity of the athlete (to estimate pure between-athlete variance). Means for different age of recruitment were adjusted to the year 1998. Means for calendar years of recruitment were estimated without adjustment for age by using a simpler fixed-effects model, in which Age was omitted.

We compared mean estimates for a given anthropometric or fitness test at different ages of recruitment by calculating the Cohen, or standardized, effect size (ES), defined as (difference in means)/SD (Cohen, 1988). To interpret the magnitude of differences, we modified Cohen’s guidelines for qualitative interpretation of effect size (Cohen, 1988) to 0.2, 0.6, and 1.2 as thresholds for small, moderate, and large effects. For the sake of parsimony we report only effects that were at least moderate in size (ES >0.6). We also calculated the likelihood that the true value of estimated difference in fitness and anthropometric tests were larger than the smallest worthwhile (practical) difference and assigned thresholds for assigning qualitative terms to chances, described in Table 1 (Liow and Hopkins, 2003). Differences in means between groups were expressed with 95% confidence intervals (95%CI).

To compare the magnitude of variation in a given anthropometric or fitness test score between levels for each gender, we divided the National standard deviation by the State. Ratios within a range of 0.9 to 1.1 were considered trivial (see justification at http://yahoogroups.com/groups/sportscience/message/2538); ratios >1.1 indicate test scores in National athletes were substantially more variable than in State athletes, whereas ratios <0.9 indicate test results in National athletes were substantially less variable.
RESULTS

Fitness Test Reliability
Reliability testing was conducted only on National-level athletes. The shuttle run had the highest TEM of 4.1% (0.4 levels), where the 20-m sprint test TEM was 1.3% (0.04 s), and the vertical jump TEM was 1.4% (0.5 cm).

Level (State versus National)
National-level players, regardless of gender, were better than State-level players on all anthropometric and fitness tests, with effect sizes ranging from 0.02 (trivial) to 0.80 (large). Differences between levels were generally small except male height (7 cm, 95%CI ±3.4 cm, ES moderate) and male body mass (6.7 kg, 95%CL ±4.0 kg, ES moderate). Standardized differences in means between levels are summarized in Table 1.

Variation within the National and State groups on any given test, as estimated by the between-subject coefficient of variation (CV), tended to be similar, with National groups being slightly less variable. Ratios comparing National to State CV (i.e. National/State) show that the variation was higher only in National players in male vertical jump (1.14) and female height (1.18). Ratios of less than 1.00, indicating State variation exceeded National variation, were evident in the male shuttle run (0.84), female skinfolds (0.86), and male sprint (0.83). Variation between female groups was similar for the 20-m sprint (0.99) and body mass (1.00). While State variation exceeded National variation on all other tests, differences were generally trivial (0.92 to 0.95). Estimations of all between-group ratios showed a similar degree
of uncertainty ($\times \div 1.10$). We have chosen to express the typical variation using a $\times \div$ factor (e.g. $\times \div 1.10$) rather than a $\pm$% factor (e.g. $\pm 10\%$) because in log-normally distributed variables, typical variation is better described with a $\times \div$ factor when the variation is more than a few percent. For example, 100 units $\times \div 2.00$ is not $\pm 10\%$, but $+100\%$ (i.e. 200 units) or $-50\%$ (i.e. 50 units).

**Gender**

In both National and State levels, males exhibited better mean scores than females on all anthropometric and fitness tests, with effect sizes ranging from 1.1 to 2.1. Substantially more variation existed among females than males only for skinfolds (by a factor of 1.23) while males had more variation in vertical jump (1.25), mass (1.25), and height (1.13). Variation between genders was similar for sprint time (1.06) and identical in shuttle run (1.00). The uncertainty of estimates of all ratios of variation between genders was $\times \div 1.10$.

**Age Differences at Recruitment (14-19 y)**

**Anthropometry**

All data are expressed in Figure 1A-C. While there was a trend for older players to have more favorable anthropometric test scores when recruited into their first year of State and National programs, the higher test scores of older athletes occasionally plateaued or reversed at approximately 17 y. National groups showed the greatest difference in height between older and younger players, with older athletes being taller between 14 and 17 y (standardized effect sizes, $\pm 95\%$ CI of ES: female: 0.93, $\pm 0.93$; male: 0.66, $\pm 1.20$). For the older juniors the height of females entering National programs declined between 17 and 19 y (0.55, $\pm 0.93$). The height difference
for State players continued to increase up to 18 y (males: 1.15, ±0.54; females: 0.54, ±1.57) (Figure 1A). While there is a substantial amount of uncertainty in some estimates, estimating growth differences in this age group is understandably imprecise.

Body mass between 14 and 17 y was higher in newly recruited older females with older players being heavier (National: 1.89, ±0.80; State: 0.73, ±0.44). However, between 17 and 19 y the older National players were lighter (1.05, ±0.87). Older male athletes had greater body mass in their recruitment year in both levels between 14 and 19 y males (National: 0.76, ±1.39; State: 2.13, ±1.54) than younger players (Figure 1B).

Skinfolds were higher in older National females between 14 and 17 y (1.15, ±1.54) but were lower in older athletes between 17 and 19 y (0.64, ±0.94). While older National males were lower in skinfolds comparing 14 and 19 y (0.80, ±1.39), older State females were higher (1.00, ±1.31) in skinfolds over the same age range (Figure 1C).

**Fitness**

There were also variable patterns in fitness tests between the different ages of recruitment. In general we observed better fitness in older players (Figure 1D-F). For National females, players recruited at 14 y jumped 4.5 cm higher (0.75, ±1.07) than 17 y athletes, but older 19 y male athletes jumped higher than 14 y players (National: 0.76, ±1.12; State: 1.13, ±0.54, Figure 2) (Figure 1D).
Older State male players up to 17 y had faster sprint times when recruited than 14 y (0.74, ±0.42) (Figure 1E). The younger National female 14 y group scored 1.7 levels higher on the shuttle run than the 17 y (1.17, ±1.38) when recruited, though there was substantial restoration of this difference comparing the 17 y group to 19 y (2.09, ±1.68). State male 16 y athletes had higher scores than 19 y (0.69, ±1.07) while older 18 y National male players had higher shuttle run scores than 14 y (1.67, ±1.96) (Figure 1C).

**Secular Differences (1996-2003)**

**Anthropometry**

All anthropometric data are shown in Figure 3A-C. There was little change in anthropometry scores in players recruited between 1996 and 2003, and any differences that existed tended to be small. Between 1999 and 2003, successive groups of National females had lower skinfolds (standardized effect sizes, ±95% confidence interval of ES: 0.89, ±0.63) and height (0.58, ±0.69), with newly recruited National males also showing lower skinfolds (0.65, ±0.65) in 2003 (Figure 3C).

**Fitness**

There was a general decline in the quality of fitness test scores between newly recruited players during the study period, although scores did not decline uniformly for all groups on all tests. Between 1996 and 2000, successive cohorts of National females increased jump height (ES: 0.64, ±0.75) while State females experienced a decline in jump height (0.83, ±0.38) (Figure 3D). Both National groups experienced a reduction in the quality of sprinting, with increases in 20-m sprint time (females: 0.70, ±1.04; males: 0.82, ±0.69). The slowing in sprint times over the study period in State
athletes was at least twice that of National athletes (National Female: 0.70 ± 1.04; National Male: 0.82 ± 0.69; State Female: 1.45 ± 0.50; State Male: 2.47 ± 0.55) (Figure 3E). The magnitude of the increase in sprint time performance was similar to the decline in aerobic fitness over the same period. Shuttle run scores were lower in both National groups (female: 1.11, ±1.03; male: 0.68, ±0.74) in 2003 than in 1996 (Figure 3F).

**Age**

The age of players at recruitment declined for both the male and female National teams over the study period, with females declining from 17.5 ± 0.9 y to 16.3 ± 1.3 y (-1.2 y, 95%CL ±0.8 y) and males declining from 18.1 ± 0.2 y to 16.2 ± 1.0 y (-1.9 y, 95%CL ±0.8 y). State groups also declined in age but to a lesser extent. Female age declined from 15.4 ± 1.1 to 14.8 ± 0.9 (-0.6 y, 95%CL ±0.4 y) and males from 15.6 ± 1.0 to 14.9 ± 1.0 (-0.7 y, 95%CL ±0.4 y).

**DISCUSSION**

The current research is the first study to comprehensively assess the effects of recruitment age and recruitment year on fitness and anthropometric testing in junior basketball. We examined the results of a standardized battery of tests on male and female players at different levels of competition with greater than 1,000 subjects over an 8-year period. We have systematically compared group means in anthropometric and fitness test results between junior male and female basketball players, State- and National-level players, players of different chronological ages, and players recruited in different calendar years. We found that estimated means varied at different ages for different groups, with test scores tending to be better for younger juniors at
recruitment age 14-17 y than older juniors age 17-19 y. While anthropometric measures were largely unchanged in recent calendar years, the speed and endurance of players have generally declined by at least small amounts. The National males and females had better scores with lower variation than State players indicating that the test protocols have potential use for talent identification purposes.

**Age Differences at Recruitment**

Older athletes generally scored better in anthropometric and fitness tests with greater improvements observed in National level players. The lower skinfolds and higher body mass with older recruitment age in the National Male group probably reflects greater development of muscle mass. This contention is supported by the higher power-to-body-mass ratio evident in improvements in vertical jump and sprint time. In State Males, the unfavorable differences in shuttle run and sprints in older players after 17 y are indicative of a poorer power to weight ratio associated with increasing skinfolds. The opposite trend can be seen in the female groups with National females decreasing skinfolds and improving fitness test scores, particularly beyond 17 y. The more favorable National player’s anthropometric and court measures with age implies that these players are fitter, likely as a consequence of more extensive and intensive physical conditioning associated with this level of program, especially beyond 17 y. State players participate in part-time training programs and generally do not undertake the comprehensive physical conditioning programs of their full-time National counterparts. Consequently State players exhibit typical adolescent gains in height and body mass but not the same magnitudes of improvements in skinfolds and measures of fitness as National-level players. The magnitude of difference between younger and older basketball players in our State players in vertical jump was somewhat less than
the difference in basketball players of the same ages (13 to 19 y) in other research (ES males: 1.13 versus 2.10; ES females: 0.05 versus 0.52) (Kellis et al., 1999).

The decline in height of National players between the recruitment age of 18 and 19 years does not indicate that individuals in this group decrease height with age, but that newly recruited players are on average shorter than newly recruited 16- and 17-year-old players. National players in the 14-17 year old age category may be recruited heavily on the basis of height, while older players are selected more on the basis of skill. Most of the taller players appear to have been recruited already by 17 years of age.

Secular Differences
The values of the test results in the current study represent the outcome of recruiting practices in State and National programs. Variable trends in anthropometry and fitness test results over the eight calendar-year period were observed: some test results showed improvement, some were relatively unchanged, and others showed a small decline. Clearly there has been a conscious decision of National female coaches to recruit taller players. There was a trend for declining body mass in both National groups, though effects were small, and skinfolds showed moderate decreases in three of the four groups studied. Comparing 2003 to 1996, most group characteristics remained stable or showed decrements in vertical jump, 20-m sprint and shuttle run performance. These findings confirm anecdotal reports that some aspects of fitness in newly recruited junior players have declined in recent years. Clearly basketball authorities need to address these important issues of player recruitment and fitness levels in junior programs.
We have also found a trend toward recruitment of younger players in both National and State programs in recent years. This trend is concerning because younger players tend to be less fit, particularly below 17y. We believe that the secular decline in fitness can be partially attributed to the decline in age of recently recruited players. Potential strategies for improving fitness levels in the future would include greater fitness development of younger players at lower levels (e.g. school and local club leagues), in addition to recruiting players close to the upper limit of their age group, though care should be taken not to overlook the early development of young tall players solely in the interest of gaining fitness. The implications of declining body size and fitness on the success of Basketball Australia is unclear. While assessing win:loss records of Basketball Australia teams over the assessed time period is tempting, many variables that determine the win:loss record are largely dependent on opposing teams. The purpose of this research was to investigate one component of many that contributes to team success. As previously discussed, body composition and fitness as been established as contributing to many facets of basketball success (Angyan et al., 2003; Groves and Gayle, 1993; Hoare, 2000; Hoffman et al., 1996; Latin et al., 1994; McKenzie, 1985) and thus declining fitness should be a concern to Basketball Australia coaches.

One possible explanation for declining fitness is that it reflects a decline in the population of Australians in this age group. Research investigating fitness of Australian school-aged children (Tomkinson et al., 2003) has demonstrated that in a similar time period of 1995 to 2000, aerobic fitness was declining at a rate of 0.4 to 0.8% per year. Our results show that the decline in aerobic fitness is approximately
1% per year when averaged across groups, ranging from a decrease of 0.8% in State males between 1996 and 2003 to greater than 15% in National females. Another possible explanation for the decline in fitness is that participation rate of basketball in boys (5-14 y) has declined by 24% from 1997 to 2003, though has slightly increased in girls (7.6%). Other sports such as swimming have increased participation dramatically in boys (38%) and girls (27%) since 1997 (McLennan, 1999; Trewin, 2005). With the overall participation rate of children in organized sport in Australia decreasing only slightly from 62% to 61% in 1997 and 2003 respectively (McLennan, 1999; Trewin, 2005), Australian basketball may be experiencing a drain of fitter players to other sports. Arguably, strategies to improve player fitness could include simply training players more or having a greater focus during practices on fitness, but the likely ramifications of such a strategy would be player burnout and declining player skill.

Program Level and Gender Differences
The National level players generally scored better on anthropometric and fitness tests than State players. The higher test scores likely reflect the National players’ greater commitment and intensity in training and possibly higher genetic capacities for these tests. These differences may be a result of greater muscle mass in National players, as reflected in greater body mass yet lower skinfolds. Fitter players may also be able to perform better during team selection camps. Our results are in accordance with studies such as Hoare (Hoare, 2000), who concluded that performance on anthropometric and fitness tests accounted for ~40% in variance of playing performance, and Hoffman et al. (Hoffman et al., 1996) that predicted that fitness test scores accounted for up to 20% of playing time when the athlete was well known to the coach or up to 80% if the
athlete was not known. Collectively this evidence underscores the importance of well
developed fitness attributes for junior basketball players.

The differing anthropometric characteristics between groups may reflect simply
variations in biological maturity and/or the recruitment strategies of coaches, with the
greater fitness levels of National players reflecting greater biological maturity, the
recruitment strategies of coaches, and/or factors relating to training history and
experience. While there were no direct measures of biological age in this study, the
height of National players plateaued one year earlier than the State level players,
possibly indicating that the National players had reached biological maturity one year
earlier then the State level players. Inspection of the fitness test results at 19 years-
old, presumably when both groups had reached biological maturity based on stability
of height, reveals National players were superior. It seems that regardless of
biological maturity, National-level players remain bigger and fitter than State-level
players.

The difference between males and females is consistent with previous data showing
adolescent males are typically taller and heavier (Malina and Bouchard, 1991), have
between 5-20% higher aerobic capacity (Beunen and Malina, 1996), and score at least
one standard deviation greater on most tests of fitness (Beunen and Malina, 1996).
Particularly large magnitudes in differences between males and females were evident
in vertical jump, skinfolds, and body mass reflecting an greater ratio of power to body
mass of males in this age group (Rowland, 1996). These gender differences are
explained by the natural difference in biological maturation, with males having a
longer pubertal growth period and faster peak height and body mass growth
(Rowland, 1996). Coaches of junior athletes should therefore expect increasingly large differences in anthropometric and court test scores between the genders as adolescence progresses.

**Implications of Test Variability**

Quantifying the variability of different tests allows coaches and sport scientists to evaluate the usefulness of a test. A test needs a typical error of measurement of less than 0.20 of the test’s between-athlete standard deviation in order to provide confident assessment of small (worthwhile) differences between athletes (Hopkins, 2000). While TEM of height and body mass are reasonably well established (Norton et al., 1996) and TEM of skinfolds is specific to each individual tester, the TEM of fitness tests needed to be established and included in interpretation of results. On the basis of our results comparing the magnitudes of typical error of measure and between-athlete variability, all of the tests examined in this study are capable of identifying meaningful differences in fitness and anthropometric characteristics between athletes. Furthermore, the National groups had higher mean scores on all tests with lower variability on most tests, underlining the value of these tests as an athlete selection tool.

The low percent variation in height (~4.5%) was initially surprising, given the apparent range of height in the different positions in basketball. However a variation of 4.5% is equivalent to 7.8 cm in the mean height of females and 8.5 cm in males, so this magnitude of variation is not unexpected. The considerable variation in body mass, skinfolds, and shuttle run likely represents differences between the demands of different positions in basketball. Anthropometric testing may be useful for assigning
players to particular positions or assessing the effectiveness of dietary practices and strength and conditioning programs. The small variation in sprint times indicates that this characteristic is relatively homogeneous, although a 4.8% variation of 3.1 s represents 0.15 s, which over 20 m equates to a displacement of 90 cm, potentially a critical distance on a basketball court. Our estimate of the smallest worthwhile difference is \(~0.04\) s equivalent to a distance of approximately 20 cm.

The basketball community must also consider individual variation in size and fitness of players, even at the elite level. The classic example often cited as the exception to the trend of basketball players being large is Spud Webb, who, despite being only 167 cm tall and weighing only 60 kg, played 12 seasons in the American National Basketball Association (NBA). Doubtless there are many other examples of extraordinary players who could easily have been overlooked if anthropometric and fitness test scores were the sole criteria for selection. Clearly a range of sport-specific methods should be used to assess basketball players (Trninic et al., 1999), but our results are consistent with other studies supporting the value of anthropometric and fitness testing for team sports (Hoare, 2000; Hoare and Warr, 2000; Pienaar et al., 1998).

Conclusions

This research utilized a very large sample size to quantify the magnitude of a variety of effects on elite Australian junior basketball players’ anthropometric and fitness test scores. We found an overall large effect of gender and a small, but still meaningful, effect of competition level. The more favorable scores with lower variability at higher levels indicated the value of fitness tests as a talent identification tool. The pattern of
overall declining test scores and player age of Australian basketball players over an eight year study period is a major issue for contemporary basketball. Coaches must consider the age of players they are selecting and the effect this will have on player fitness levels. The value of fitness and anthropometric testing is demonstrated by the National level players having better scores with lower between-subject variability. Basketball organisations and individual teams should benefit from the administration of anthropometric and fitness testing of junior players.
REFERENCES


Figure 1 - Group estimates for National Females (●), National Males (■), State Females (○), and State Males (□) showing the scores of different groups throughout the age range, adjusted to recruitment year 1998. Error bars represent 95% confidence limits while the filled bars (●) represent the typical error of measure for the test and the open bars (□) represent the between-subject SD averaged over all groups. Group means have been slightly offset from age for clarity.
Figure 2: Scatter plot to illustrate additional detail to the origins of the State Male plot of Figure 1D, indicating the age trend of State male vertical jump (N=1164). This figure represents a typical plot for the age effect of any test, showing the distribution of individual players and the mean trend line from 13 to 19 y of age. In this example, older State Male players are jumping higher than younger players. The graph plots individual player test scores (●) while the solid trend line refers to the modeled estimate over time, and the dotted lines (……) refer to the upper and lower 95% confidence limits for the true mean.
Figure 3 - Group estimates showing actual trends for National Females (●), National Males (■), State Females (○), and State Males (□) comparing year of recruitment between groups. Error bars represent 95% confidence limits while the filled bars () represent the typical error of measure for the test and the open bars () represent the between-subject SD averaged over all groups. Group means have been slightly offset from year for clarity.
Table 1 - Effect sizes and qualitative descriptors of differences between levels of players (State vs National). Positive values of the effect size indicates National scores were greater than State. In skinfold and sprint tests, lower scores are better. Probability reflects the likelihood that National level players were at least a small effect size better (>0.2*SD) than State level players.

<table>
<thead>
<tr>
<th>Test</th>
<th>Gender</th>
<th>Mean Score ± SD</th>
<th>Magnitude of National - State Effects</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>State N</td>
<td>National N</td>
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<tr>
<td>Vertical Jump (cm)</td>
<td>F</td>
<td>45.6 ±6.5</td>
<td>2262</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>59.1 ±7.3</td>
<td>2372</td>
</tr>
<tr>
<td>Shuttle (levels)</td>
<td>F</td>
<td>9.3 ±1.6</td>
<td>2163</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>11.2 ±1.6</td>
<td>2242</td>
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<tr>
<td>Skinfolds (mm)</td>
<td>F</td>
<td>103.4 ±28.3</td>
<td>1377</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>68.4 ±22.3</td>
<td>1389</td>
</tr>
<tr>
<td>Sprint (s)</td>
<td>F</td>
<td>3.42 ±0.16</td>
<td>2217</td>
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<td></td>
<td>M</td>
<td>3.15 ±0.16</td>
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<tr>
<td>Mass (kg)</td>
<td>F</td>
<td>65.6 ±8.6</td>
<td>2370</td>
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<td></td>
<td>M</td>
<td>77.3 ±11.0</td>
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<tr>
<td>Height (cm)</td>
<td>F</td>
<td>174.3 ±7.0</td>
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<tr>
<td></td>
<td>M</td>
<td>187.8 ±8.9</td>
<td>2340</td>
</tr>
</tbody>
</table>

M=male, F=female; 95%CI: 95% confidence interval of the true effect size

*aCriteria for magnitude: <0.2 trivial, 0.2 – 0.6 small, 0.6 – 1.2 moderate, > 1.2 large

*bThresholds for assigning qualitative terms to chances of substantial effects were as follows: <1%, almost certainly not; <5%, very unlikely; <25%, unlikely; <50%, possibly not; >50%, possibly; >75%, likely; >95%, very likely; >99% almost certain.