

Cardiorespiratory Endurance, Flexibility and Overall Motor Fitness Profile of Forward and Backward Basketball Players: Evidence from State-Level Male Athletes in Gwalior, India

Shubham Dilip Itankar

Assistant Professor, Ramdeobaba University

Abstract

Background: Aerobic capacity and joint mobility support repeated high-intensity effort and safe movement in basketball, but their relationship with playing position has received limited attention among Indian state-level players.

Objective: To compare cardiorespiratory endurance and flexibility between forward and backward male basketball players of Gwalior, and to describe their overall five-component motor fitness profile.

Methods: Fifty male players aged 17–21 years (25 forward, 25 backward) completed the 12-minute run–walk (Cooper) test and the sit-and-reach test, in addition to the 50-m dash, shuttle run and standing broad jump. Groups were compared with independent-samples t tests, Hedges' g with 95% confidence intervals and Mann–Whitney U tests. An overall profile was examined using a composite index (the mean of five sign-aligned z scores) and Hotelling's T^2 .

Results: Backward players covered more distance in the Cooper test (2543 ± 47 m vs 2392 ± 64 m) and reached farther in the sit-and-reach test (32.5 ± 1.6 cm vs 27.9 ± 1.7 cm); both differences were significant ($p < 0.001$) and very large (Hedges' $g = 2.67$ and 2.72). The composite index also separated the groups ($p < 0.001$), and the five-variable multivariate test was significant ($T^2 = 107.5$, $p < 0.001$).

Conclusion: Backcourt players had better aerobic endurance, hamstring-related flexibility and overall motor fitness than frontcourt players in this sample. Position-sensitive conditioning, including aerobic and mobility work for forward players, is warranted, but the findings need confirmation with body-size measures and larger samples.

Keywords: basketball; playing position; cardiorespiratory endurance; Cooper test; flexibility; sit-and-reach; motor fitness profile; India

Introduction

Although basketball is often described in terms of speed and power, its aerobic demands are far from trivial. Match play is intermittent, but physiological monitoring shows that players work at a high proportion of their maximal heart rate for much of the game (McInnes et al., 1995; Abdelkrim et al., 2007), and a systematic review of match-play demands highlights the importance of recovering quickly between repeated high-intensity actions (Stojanović et al., 2018). A player with greater aerobic capacity can recover more quickly between efforts and is better able to maintain movement quality and decision-making as fatigue builds.

Aerobic demands are unlikely to be uniform across positions. In elite men's basketball, point guards have been reported to show the best endurance on an intermittent running test, whereas centres and power forwards are the tallest and heaviest players (Ben Abdelkrim et al., 2010). Pojskic et al. (2015) found that guards and forwards had higher aerobic power than centres, while centres had higher absolute anaerobic power. These results suggest that the aerobic profile is shaped by both role and body size, and that the picture can change depending on how positions are grouped.

Flexibility is discussed less often than endurance, yet a basketball player continually lunges, pivots, lands, slides and reaches. The sit-and-reach test is one of the most widely used field measures of flexibility. A meta-analysis found that it is a reasonably valid indicator of hamstring extensibility but a weaker indicator of lumbar extensibility (Mayorga-Vega et al., 2014), and it should be interpreted accordingly. Whether guards and forwards differ in this simple measure has received little attention at state level in India.

Endurance and flexibility are also best understood alongside other components of motor fitness. A coach rarely cares about one test in isolation; the more useful question is how a player's whole profile compares with that of teammates in other positions. In a companion paper from the same dataset we reported speed, agility and explosive leg power; here we focus on endurance and flexibility and then combine all five components into an overall profile.

The aims of this study were to compare cardiorespiratory endurance and flexibility between forward and backward male basketball players of Gwalior, and to describe their overall motor fitness profile. We tested the following null hypotheses: there is no significant difference between forward and backward players in (H_{01}) cardiorespiratory endurance, (H_{02}) flexibility, or (H_{03}) overall motor fitness, assessed jointly across all five components.

Methodology

Study design

The study had a cross-sectional, comparative design in which two intact groups, forward and backward players, were compared on a single occasion. Playing position was the grouping factor, and no intervention was applied (Thomas & Nelson, 2001).

Participants

Fifty state-level male basketball players from Gwalior participated. They were recruited by purposive sampling through local academies. Inclusion criteria were: age 17–21 years; a clearly defined playing position; at least two years of competitive experience at district or state level; freedom from acute or chronic injury at the time of testing; and written informed consent (with parental or guardian consent for players under 18). Twenty-five players were forwards (small forwards, power forwards and centres) and twenty-five were backward players (point guards and shooting guards), with positions assigned by their coaches. Both groups had the same mean age (19.12 ± 1.27 years). Height and body mass were not recorded.

Testing procedures

Data were collected over two consecutive days at a standardised venue in Gwalior with the help of trained officials and academy coaches. The two tests that are the focus of this paper were as follows.

- *Cardiorespiratory endurance (12-minute run–walk test)*. Following Cooper (1968), players covered as much distance as possible in 12 minutes on a 400-m athletics track, running or walking as needed. Officials stationed around the track marked each player's final position, and total distance was measured to the nearest metre. Players ran in groups under supervision.
- *Flexibility (sit-and-reach test)*. Players sat barefoot with legs extended and the soles of the feet flat against a standard sit-and-reach box. With one hand on top of the other, they pushed the indicator slowly forward along the scale as far as possible and held the position for at least two seconds. The best of three trials was recorded in centimetres.

For the overall profile, the results of three further tests, the 50-m dash (speed), 10×5 m shuttle run (agility) and standing broad jump (explosive leg power), were also used. Their procedures are described in the companion paper.

Ethical considerations

Participation was voluntary and players could withdraw at any time. Written informed consent was obtained in line with the principles of the Declaration of Helsinki (World Medical Association, 2013), and each player was told what each test involved before beginning.

Statistical Analysis

Analyses were performed on individual raw scores. Means and standard deviations were computed for each group. Normality was examined with the Shapiro–Wilk test (Shapiro & Wilk, 1965) and homogeneity of variance with Levene’s test (Levene, 1960). Group differences in each test were assessed with independent-samples *t* tests (two-tailed, $\alpha = 0.05$, $df = 48$), with Welch’s correction also computed (Delacre et al., 2017). Mean differences are reported with 95% confidence intervals. Effect sizes were expressed as Hedges’ *g* with approximate 95% confidence intervals (Lakens, 2013), and interpreted with the thresholds of Hopkins et al. (2009): 0.2 small, 0.6 moderate, 1.2 large, 2.0 very large, 4.0 extremely large. Mann–Whitney *U* tests (Mann & Whitney, 1947) served as a distribution-free check. A Bonferroni-adjusted threshold ($0.05/2 = 0.025$) was considered for the two focal tests and did not alter any conclusion.

Estimated maximal oxygen uptake was derived from Cooper-test distance using Cooper’s (1968) regression, $\text{VO}_{2\text{max}} (\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = 22.351 \times \text{distance (km)} - 11.288$. These values are indicative only, because the equation was developed in a different population and has not been validated in this sample.

To describe the overall profile, each of the five test scores was converted to a *z* score using the mean and standard deviation of all 50 players. Scores for the 50-m dash and shuttle run were multiplied by -1 so that higher values always meant better performance, and the five *z* scores were averaged into a composite index per player. Because the *z* scores are relative to this sample, the index describes standing within the sample and is not a normative score. The composite was compared between groups with a *t* test, and the five variables were compared jointly with Hotelling’s T^2 (Hotelling, 1931), a multivariate generalisation of the *t* test. Pearson correlations described the association between endurance and flexibility. Calculations were carried out in Python 3 with the SciPy library.

Results

Table 1 presents the descriptive statistics and *t* test results for endurance and flexibility, and Table 2 the effect sizes and non-parametric comparisons. Individual scores are plotted in Figure 1. Age did not differ between groups (19.12 ± 1.27 years in each).

Table 1. Descriptive statistics and independent-samples *t* test results for endurance and flexibility (*n* = 25 per group)

Variable	Forward (M ± SD)	Backward (M ± SD)	Mean diff. (F – B)	<i>t</i> (df = 48)	Welch <i>t</i>	<i>p</i>
12-min Cooper run (m)	2392 ± 64	2543 ± 47	-151.5	-9.58	-9.58	< 0.001
Sit-and-reach (cm)	27.9 ± 1.7	32.5 ± 1.6	-4.6	-9.77	-9.77	< 0.001

Note. Higher values indicate better performance on both tests. Levene's test showed homogeneous variances (*p* = 0.174 and 1.000). Shapiro–Wilk *p* values exceeded 0.05 in all groups (range 0.160–0.657).

Table 2. Mean differences, effect sizes and non-parametric comparison

Variable	Mean (95% CI)	diff. (95% CI)	Hedges' g (95% CI)	Relative diff.	Mann–Whitney U	p
12-min Cooper run (m)	-151.5 (-183.3 to -119.7)	2.67 (1.90–3.43)	6.0%	16.5	< 0.001	
Sit-and-reach (cm)	-4.6 (-5.6 to -3.7)	2.72 (1.95–3.49)	14.2%	16.0	< 0.001	

Note. Differences are forward minus backward. Hedges' *g* is shown as an absolute value. Relative difference is a percentage of the backward-group mean.

Figure 1. Distribution of individual scores by playing position for (a) the 12-minute Cooper run, (b) the sit-and-reach test and (c) the composite motor fitness index (mean of five *z* scores; higher = better). Boxes show the median and interquartile range; dots are individual players.

Backward players covered 151 m more than forward players in 12 minutes (95% CI 120–183 m; 6.0% farther). Using Cooper's equation, these distances correspond to estimated VO_2max values of about $45.6 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for backward and $42.2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for forward players. On the sit-and-reach test, backward players reached 4.6 cm farther (95% CI 3.7–5.6

cm). Both differences were statistically significant ($p < 0.001$) and very large ($g = 2.67$ and 2.72); Welch and Mann–Whitney analyses agreed. Null hypotheses H_{01} and H_{02} were rejected.

Table 3. Composite motor fitness index and multivariate comparison

Measure	Forward	Backward	Test result	Hedges' g
Composite index (mean z score)	-0.81 ± 0.61	0.81 ± 0.53	$t(48) = 10.01, p < 0.001$	2.79
Hotelling's T^2 (all five tests)	—	—	$T^2 = 107.5, F(5, 44) = 19.71, p < 0.001$	—
Hotelling's T^2 (Cooper + sit-and-reach)	—	—	$T^2 = 95.7, F(2, 47) = 46.86, p < 0.001$	—

Note. The composite index is built from sample-based z scores, so the two group means are necessarily symmetrical around zero. Higher values denote better overall performance.

On the composite index, forward players averaged -0.81 (SD 0.61) and backward players 0.81 (SD 0.53), a difference of very large magnitude ($g = 2.79; p < 0.001$; Mann–Whitney $p < 0.001$). Only 5 of the 25 forward players scored above the lowest-scoring backward player. The five variables considered jointly also separated the groups ($T^2 = 107.5, F(5, 44) = 19.71, p < 0.001$), so H_{03} was rejected.

Endurance and flexibility were strongly associated across the full sample ($r = 0.99, p < 0.001$) and within each group (forward $r = 0.96$; backward $r = 0.996$; both $p < 0.001$).

Interpretation of Results

Both focal tests point the same way. Backward players covered roughly 150 m more in the Cooper test, which is a gap of about 6% in distance. On a continuous running test, that is a clear difference in aerobic capacity, and the estimated $VO_{2\max}$ values (about 42 versus 46 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), although indicative only, are meaningfully higher in the backward group. The sit-and-reach difference of about 4.6 cm is also sizeable relative to the group standard deviations of 1.6–1.7 cm.

The effect sizes (g of about 2.7) are in the “very large” category. Although the Hopkins scale makes such values easy to label, they are rare in sport-science studies and should be viewed as a feature of this particular sample. The confidence intervals are narrow, so the

differences are precisely estimated for these 50 players, but whether comparably wide gaps would be found in other settings is an open question.

The composite index and the multivariate test lead to a broadly similar conclusion: when the five motor fitness tests are considered together, backward players hold a better overall profile. The very high correlations between endurance and flexibility (and, as noted in the companion paper, between all five tests) should temper any attempt to interpret the five components as independent attributes. The players who did well on one test generally did well on all of them, so the group differences may reflect a general fitness dimension, such as training status or body size, as well as position-specific adaptations. The data cannot separate these explanations.

6. Discussion

The superior aerobic performance of backward players is in line with what is known about the role. Guards typically cover more ground and accumulate more transitions between offence and defence, and previous work has linked guard positions with higher endurance and aerobic power than the tallest, heaviest players (Ben Abdelkrim et al., 2010; Pojskic et al., 2015). Our results extend this pattern to state-level players in a regional Indian setting. Elite-level work suggests that guards and forwards may differ less than guards and centres (Pojskic et al., 2015). Because our forward group pooled small forwards, power forwards and centres, any real forward–centre differences are hidden, and the average forward value may be pulled down by the largest players.

Body size is the most important unmeasured factor in the endurance result. The Cooper test requires players to carry their own body mass over a fixed time, so heavier players are at a mechanical disadvantage, independent of cardiovascular function. In the absence of height, body mass or body composition, we cannot tell how much of the 150-m gap reflects oxygen-transport capacity and how much reflects the cost of running with more mass. In addition, the Cooper test is a continuous run, whereas basketball is intermittent. Intermittent field tests such as the Yo-Yo test have been used to assess position-specific endurance in elite players (Ben Abdelkrim et al., 2010), and including one would improve specificity.

The flexibility finding may reflect the movement repertoire of backcourt players, who spend much of the game in low, athletic stances, sliding and lunging. Equally, it may reflect differences in limb and trunk proportions, because reach on the sit-and-reach test is partly determined by relative limb length (a taller player with long legs and a short trunk is at a

disadvantage). The test mainly reflects hamstring extensibility and is less informative about the lumbar spine (Mayorga-Vega et al., 2014), so we avoid generalising to overall flexibility. We also did not record injury history, so we cannot comment on whether the lower flexibility in forwards is associated with greater injury risk.

These findings suggest several practical steps for coaches. Forward players, in particular those who are largest, may benefit from structured aerobic development, such as interval running and court-based conditioning, matched to the intermittent nature of the game. A regular mobility programme addressing the hamstrings and hips could be added to routine warm-ups and cool-downs. Backward players already show strengths in these domains, but they should not neglect strength and contact-related qualities, which we did not measure. Finally, a simple battery of field tests of the kind used here is inexpensive and could be repeated across the season to monitor individual progress, whereas the group means in this paper should be treated as provisional reference values for comparable players, not as selection thresholds.

Limitations

The limitations of this study are those of a modest, purposive, single-city sample of male players, with only two broad positional groups. The cross-sectional design prevents conclusions about training effects or selection. Body size, maturation, nutrition, sleep and training history were not measured. The Cooper test was run in groups, which may introduce pacing effects, and the sit-and-reach test is only a proxy for flexibility. Hand timing and the lack of blinding may have introduced measurement bias. The unusually large effects and very high correlations among tests suggest that the results should be replicated in an independent sample, preferably with electronic timing and body-size data, before they are used to set standards.

Conclusion

In this sample of state-level male basketball players from Gwalior, backward players showed significantly greater cardiorespiratory endurance (about 151 m farther in the 12-minute test) and flexibility (about 4.6 cm farther in the sit-and-reach test) than forward players, and a better overall motor fitness profile when all five components were combined. All three null hypotheses were rejected. The results support position-sensitive conditioning in which forward players receive additional aerobic and mobility work. Larger, multi-site studies that include

body-size measures, intermittent endurance tests and longitudinal follow-up are needed to determine how far these differences reflect training, selection or body composition.

References

- Abdelkrim, N. B., El Fazaa, S., & El Ati, J. (2007). Time–motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British Journal of Sports Medicine*, 41(2), 69–75.
- Ben Abdelkrim, N., Chaouachi, A., Chamari, K., Chtara, M., & Castagna, C. (2010). Positional role and competitive-level differences in elite-level men's basketball players. *Journal of Strength and Conditioning Research*, 24(5), 1346–1355. <https://doi.org/10.1519/JSC.0b013e3181cf7510>
- Cooper, K. H. (1968). A means of assessing maximal oxygen intake: Correlation between field and treadmill testing. *JAMA*, 203(3), 201–204.
- Delacre, M., Lakens, D., & Leys, C. (2017). Why psychologists should by default use Welch's *t*-test instead of Student's *t*-test. *International Review of Social Psychology*, 30(1), 92–101. <https://doi.org/10.5334/irsp.82>
- Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, 41(1), 3–13.
- Hotelling, H. (1931). The generalization of Student's ratio. *The Annals of Mathematical Statistics*, 2(3), 360–378.
- Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for *t*-tests and ANOVAs. *Frontiers in Psychology*, 4, Article 863.
- Levene, H. (1960). Robust tests for equality of variances. In I. Olkin (Ed.), *Contributions to probability and statistics* (pp. 278–292). Stanford University Press.
- Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The Annals of Mathematical Statistics*, 18(1), 50–60.
- Mayorga-Vega, D., Merino-Marban, R., & Viciano, J. (2014). Criterion-related validity of sit-and-reach tests for estimating hamstring and lumbar extensibility: A meta-analysis. *Journal of Sports Science and Medicine*, 13(1), 1–14.

- McInnes, S. E., Carlson, J. S., Jones, C. J., & McKenna, M. J. (1995). The physiological load imposed on basketball players during competition. *Journal of Sports Sciences*, 13(5), 387–397.
- Pojškic, H., Šeparović, V., Užičanin, E., Muratović, M., & Mačković, S. (2015). Positional role differences in the aerobic and anaerobic power of elite basketball players. *Journal of Human Kinetics*, 49, 219–227.
- Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika*, 52(3–4), 591–611.
- Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanović, Z. (2018). The activity demands and physiological responses encountered during basketball match-play: A systematic review. *Sports Medicine*, 48(1), 111–135.
- Thomas, J. R., & Nelson, J. K. (2001). *Research methods in physical activity* (4th ed.). Human Kinetics.
- World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA*, 310(20), 2191–2194.