BIOMECHANICS OF BALANCE: PARADIGMS AND PROCEDURES

Jackie L. Hudson

California State University, Chico, CA, USA

INTRODUCTION

Balance, like coordination, is understood by virtually everyone to be a critical component of skillful movement. Yet there exists relatively little biomechanical research into how balance is employed and improved by performers of disparate abilities in different activities. One explanation for this dearth of research is that our traditional conceptions of balance may be too limiting if our goal is to measure and modify balance in the context of sports. With this goal in mind, I will review several definitions and conceptions of balance, elaborate and integrate some of these approaches, and propose a paradigm and procedures for assessing balance during physical activity.

REVIEW

Our definitions and conceptions of balance are rooted in many traditions. As members of secular society we are informed by both formal and informal interpretations of balance. For example, a prominent definition of balance is equilibrium (The American Heritage Dictionary of the English Language, 1980). This definition draws from and is illustrated by a balance scale which is used to determine if two items have equal weight. Another, newer, definition of balance is harmonious proportions. In this sense a balanced diet would have harmonious rather than equal proportions of carbohydrate, protein, and fat. The predicament for biomechanists is to determine specifically what aspects of balance should be in either equal or harmonious proportions.

Judging from the vernacular, most observers of movement can recognize obvious problems with balance. Typically, to "lose balance" means to fall or fail to maintain balance. Being "off balance" means to deviate from the expected, smooth control of balance; this term is applied broadly to the mover who is at risk of losing balance as well as to the unorthodox mover who is, say, throwing from the right foot when the left foot was expected. In their favor, these popular terms allow us to distinguish poor skill (i.e., inability to maintain balance) from mediocre skill (i.e., inability to control balance) even as some unusual, but contextually appropriate, movements are misclassified. Unfortunately, the colloquial language does not extend to the description of positive examples of balance or to the quantification of any examples of balance.

Scholars of motor ability testing began the tradition of quantifying balance in the 1930s. In general, time was the criterion, and tasks were dichotomized as testing either static balance (e.g., standing on one leg) or dynamic balance (e.g., walking along a narrow beam). Although the criterion was crude and the tasks were contrived rather than common to sports or daily life, this research was popular until the primary investigators discovered that there was "virtually no relationship between static and dynamic balance" (Thomas & Nelson, 1990, p. 373). Rather than accept the disconnected duality of static vs. dynamic balance, Hellebrandt (1940) noted that a person in static stance was constantly swaying. In other words, there are periods of mobility within periods of stability.

The biomechanics and kinesiology literature on balance is both a composite and a critique of the preceding conceptions. In many texts, particularly those oriented to mechanics (e.g., Adrian & Cooper, 1995; Hamill & Knutzen, 1995), balance is equated with equilibrium. But, as Kreighbaum and Barthels (1990, p. 310) point out, true equilibrium in human activities is practically nonexistent because "the body is always experiencing some kind of movement change." Greenlee (1981), in a qualitative text, uses the terms harmony, loss of balance, and off-balance. Garhammer (1989) discusses static or dynamic balance as occurring when the line of gravity (LoG) passes inside (static) or outside (dynamic) the base of support (BoS). Many authors relate balance to stability: Hall (1995) implies a balance continuum by saying that stability can be minimized or maximized. Stability's antipode is instability for Broer (1960), but for Luttgens et al. (1992) it is mobility. While Luttgens et al. posit an inverse relationship between stability and mobility, Moore and Yamamoto (1988) echo Hellebrandt (1940) by saying that an activity can have both stability and mobility at the same time. Kreighbaum and Barthels acknowledge that context is critical when they describe balance as movement control for a given purpose. Similarly, balance is defined as the ability to maintain or control upright body position (Dictionary of the Sport & Exercise Sciences, 1991). Hay (1993) mentions the stabilizing moment of a wrestler in terms of his weight, and numerous authors discuss LoG and BoS, but no one has suggested a comprehensive method of operationalizing research on balance. What are the quantifiable constituent elements of balance that can distinguish among movers with different control (i.e., skill)?

PARADIGM

Drawing from the foregoing discussion, I propose that the constituent elements of the biomechanics of balance are stability and mobility. After all, if a standing person has perpetual movement and a moving person (e.g., a runner) has intervals of stability, then it seems prudent to examine both stability and mobility in any analysis of balance. Because horizontal, rather than vertical, forces appear to be the greatest threat to balance, the focus here is horizontal.

The stability component of balance refers to the body's resistance to change of horizontal position. The critical features of stability are the body's position, typically represented by LoG, and the BoS. Each of these features can vary independently along its own continuum. The range of values for LoG and BoS in the anteroposterior (A-P) plane are depicted in Figure 1. The greatest potential for stability is represented at the centers of the continua, and the greatest potential for instability is represented at the ends. Because both LoG and BoS are elements of posture, they often can be assessed at the same time.

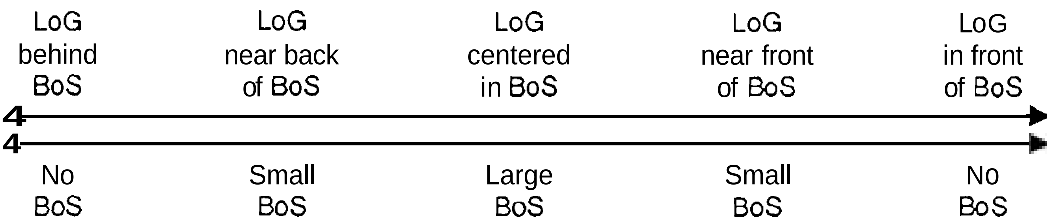

Figure 1. Stability Continua

The mobility component of balance refers to the horizontal movement of the body. Variations in the direction and velocity of the body in the A-P plane are depicted on the continuum in Figure 2. The greatest mobility is shown at the ends of the continuum and the greatest immobility is shown at the center.

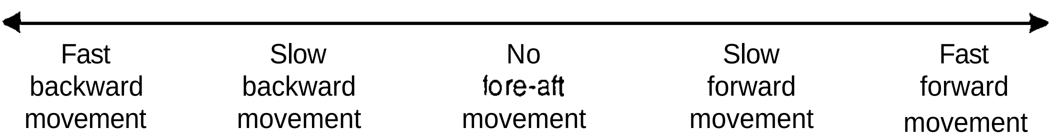

Figure 2. Mobility Continuum

The relationship between stability and mobility is complicated. First, there is generally an interplay between stability and mobility. For example, an increase in stability (e.g., enlarging the BoS) may lead to a decrease in mobility (e.g., slowing of forward movement). Second, the interplay between stability and mobility may be more or less harmonious. That is, alterations in one component may lead to either beneficial or detrimental changes in the other component. Third, the desirable proportions of stability and mobility depend on the context: An archer desires high stability and low mobility, a sprinter wants low stability and high mobility, and a ballerina seeks low stability and low mobility.

In sum, balance is defined here as the harmonious and contextually appropriate interplay of stability and mobility of the body with respect to its BoS. Presumably, less skillful performers and less successful performances are characterized (in many cases) by less harmonious or less appropriate control of stability and mobility. For a better understanding of this, we can investigate how movers of distinct skill in diverse sports resolve the riddle of balance.

PROCEDURES

Measuring balance is problematic. Because the active body is rarely in equilibrium, stability and mobility are usually fluctuating in both A-P and M-L planes. Depending on the context of inquiry, we may choose to use certain simplifying assumptions. For example, the body can be represented by a point mass. Thus, in a video analysis the position and velocity of the body's LoG can be used respectively to assess stability and mobility. Analogously, center of pressure (instead of LoG) and shear force (instead of velocity) can be obtained with a force plate. Other simplifying assumptions include using a representative rather than an actual BoS, expressing measurements relative to the size of the performer, focusing only on the primary plane of movement, and using either critical intervals or instances of time. As we gain a more refined understanding of how performers regulate balance, our procedures should also become more refined.

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