TIME-COURSE OF COUNTERMOVEMENT JUMP VARIABLES DURING RECOVERY FROM MATCH FATIGUE: ANALYSIS OF AN INDIVIDUAL ATHLETE

Antonia Gregoriou, Husan Thapa, and Nicholas P. Linthorne

Division of Sport, Health and Exercise Sciences, Department of Life Sciences, Brunel University London, Uxbridge, United Kingdom

The aim of this study was to determine whether measures of countermovement jump variables obtained from a force platform can be used to monitor the time-course of recovery from match fatigue in an individual athlete. One female football player performed 60 jumps over four days on a *Kistler* force platform to produce baseline measures of jump variables. A football match was then played to induce neuromuscular fatigue and the player's recovery from the match was monitored by recording about 100 jumps over several days following the match. Some jump variables showed evidence of a change immediately after a match but the changes were not substantial. The jump data did not show clear evidence of an exponential recovery to baseline after the match. Any patterns in the recovery data were probably random fluctuations rather than true trends in the data. We conclude that the time-course of recovery for this player was too small to detect using the selected countermovement jump variables in the days after a football match.

KEYWORDS: football, neuromuscular fatigue, soccer, vertical jump.

INTRODUCTION: Athletes in team field sports such as football and rugby usually perform many explosive actions over the course of a match and this can induce substantial neuromuscular fatigue in the athlete. An athlete's response to match fatigue often follows a biphasic pattern; there is an immediate decrease in performance with considerable recovery after a few hours, but performance can decrease again about a day later with a gradual recovery over the next few days. The acute fatigue arises from the depletion of energy reserves and the accumulation of metabolites and so depends on the duration and rate of the physiological work performed by the athlete's muscles, whereas the delayed fatigue probably arises from microtrauma to muscle fibres and so depends on the magnitude and duration of the physical loads applied to the athlete's muscle-tendon units.
Most sports trainers would like to have detailed information on the fatigue status of the athlete in the days after a match to help guide the athlete's recovery and training program. A force platform is commonly used to monitor fatigue status through measures of countermovement jump height. However, it is not clear whether jump height is a reliable measure for monitoring the time-course of recovery of the individual athlete. Also, some investigators have suggested that jump height might not be the most sensitive indicator of an athlete's fatigue status; a fatigued athlete might modify their jumping technique to compensate for neuromuscular fatigue and so achieve a jump height that is close to their unfatigued jump height (Gathercole, Sporer, Stellingwerff, & Sleivert, 2015).
The aims of this study were 1) to determine whether variables obtained from a countermovement jump on a force platform can be used to monitor the time-course of recovery from match fatigue in the individual athlete, and 2) to identify the jump variables that are the most sensitive indicators of full recovery from fatigue. The primary hypothesis was that the jump variables obtained from a force platform are sufficiently reliable and the changes induced by a match are sufficiently large that the time-course of the recovery of the jump variables in an individual athlete can be detected in the days after a match. The secondary hypothesis was that some technique variables show a longer recovery time than jump height.

METHODS: This study used a single-subject experimental design with one female football player (age 23 years; height 1.70 m; mass 56 kg). The participant's baseline measures were determined by recording jump variables in 60 jumps over four days. A football match was then played to induce neuromuscular fatigue. The participant's recovery from the match was monitored by recording jump variables in about 100 jumps over several days following the match.

The jump variables were obtained from ground reaction force data which was measured with a force platform. Our choice of jump variables was guided by the mechanics of a countermovement jump (Linthorne, 2001; in press). The jump performance variables were: a) the jump height using the impulse–momentum method; b) the jump height using the flight-time method; and c) the peak upward speed. The jump technique variables in the downward countermovement phase of the jump were: d) the countermovement depth; e) the maximum downward speed; f) the minimum force; and g) the force at the bottom of the countermovement. The jump technique variables in the upward propulsion phase of the jump were: h) the maximum force, and i) the take-off height.

The baseline jump testing sessions were conducted three times a day over four consecutive days during the early pre-season phase of the participant's yearly cycle. All jump testing sessions took place in the same indoor biomechanics laboratory. In each test session the participant performed up to seven maximal-effort countermovement jumps with at least one minute of rest between each jump. Arm movement was constrained by having the participant grip a lightweight aluminium rod that was positioned across the shoulders. The participant wore lightweight sports clothing and the same footwear in all the jump testing sessions. The participant stood upright and stationary on a 60 × 40 cm Kistler piezoelectric force platform (type 9281B11; Kistler Instrumente, Winterthur, Switzerland). After about two seconds the participant initiated a jump using a downward countermovement to a self-selected depth, followed immediately by a maximal-effort upward jump. The participant was instructed to keep constant downward pressure on the rod throughout the jump and to aim for maximum height in the flight phase of the jump. Time traces of the vertical ground reaction force for the jumps were obtained using *BioWare* biomechanical analysis software (version 5.2; Kistler Instrumente, Winterthur, Switzerland) with the sampling rate set to 1000 Hz. The jump variables were obtained using the methods reported by Linthorne (in press).

The time-course of the recovery from neuromuscular fatigue was examined using two studies that had different timescales. Study 1 used a long timescale (5 days). Three days after the last day of the baseline jump testing a simulated football match was used to induce neuromuscular fatigue in the participant. Recovery jump testing was conducted about 20 minutes after the match and over the five days following the match with three jump testing sessions per day. Study 2 used a short timescale (2 days). Several weeks after the first study a competition football match was used to induce neuromuscular fatigue in the participant. Recovery jump testing was conducted about 60 minutes after the match and over the two days following the match with eight jump testing sessions per day.

To assess the time-course of the jump variables during the recovery, each jump variable was plotted against time and a loess curve was fitted to reveal the underlying trend on each of the days. The optimum loess smoothing was determined by examining the residuals of the fit. The time-course of the jump variables was also assessed by fitting an exponential curve to the data. The recovery of a jump variable was assumed to follow a first-order kinetics model where the rate of recovery is proportional to the departure from full recovery. The fitted curve was of the form $X = X_p\,(1 - e^{-t/\tau})$, where X is the jump variable, t is time, τ is the time constant of recovery, and X_p is the plateau value of the jump variable (as $t \rightarrow \infty$).

This investigation also used self-reported measures of well-being to monitor neuromuscular fatigue. A well-being questionnaire was used that assessed the participant's fatigue, sleep quality, general muscle soreness, stress level, and mood on a five-point scale (Hooper & Mackinnon, 1995). Overall well-being was determined by summing the five scores. The participant completed the questionnaire before and after the football matches and just before the first jump test session on each of the baseline testing days and recovery testing days.

RESULTS: In the baseline jump testing sessions the participant produced a consistent set of jumps with small variability in the jump variables. Loess fits and linear fits to the baseline time sequences did not reveal evidence of a longitudinal trend or diurnal oscillation in any of the jump variables (Figure 1). The well-being score remained relatively stable over the four days

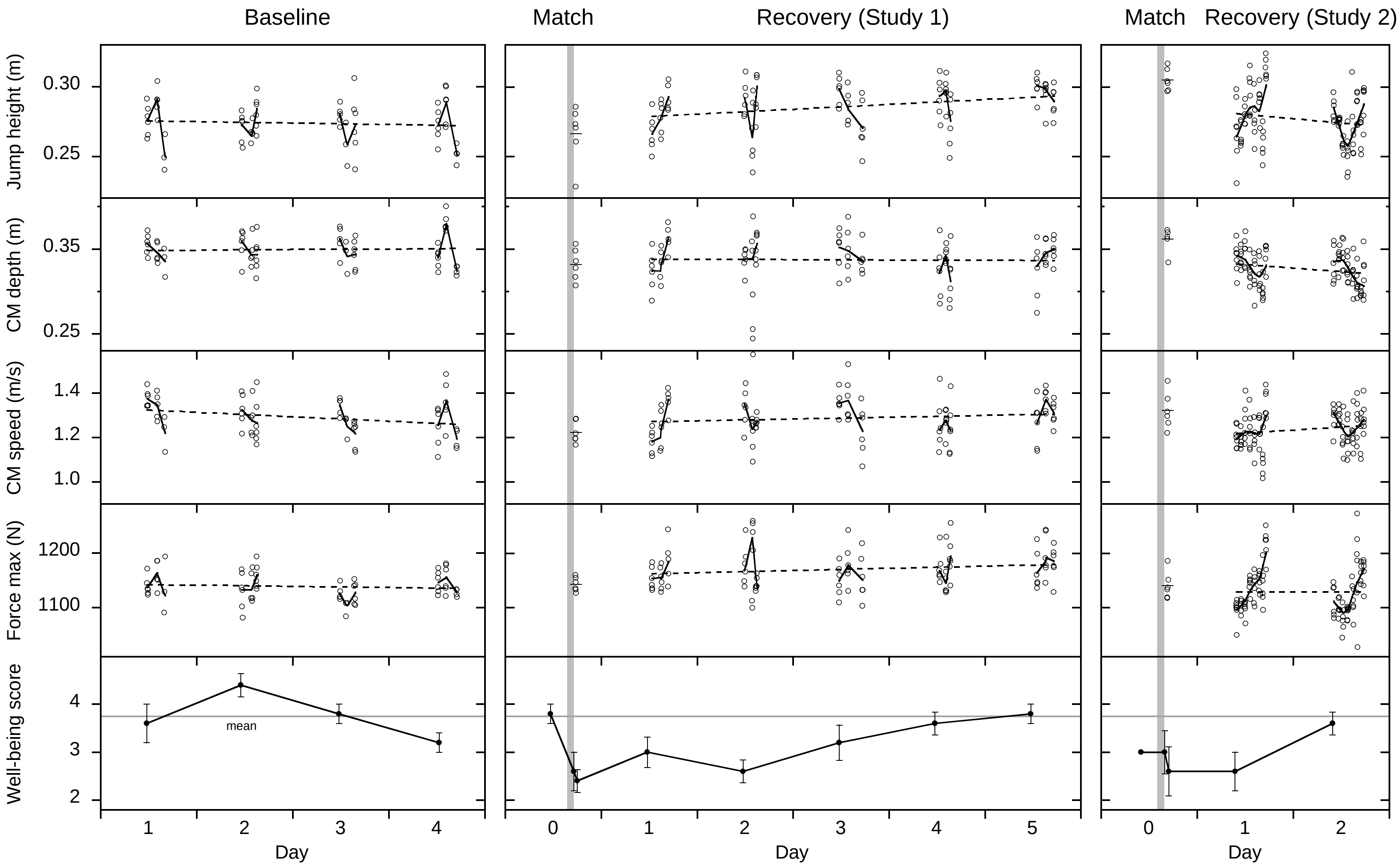

Figure 1: Baseline and recovery data for a jump performance variable (jump height using the impulse-momentum method), three jump technique variables (countermovement depth; countermovement speed, maximum force), and a well-being score. The two football matches are indicated by a vertical grey line. The solid line in the jump variable plots is a loess fit to the data for each day. The dashed lines are linear fits to the baseline data and the recovery data. None of the jump variables showed clear evidence of a time-course in recovery after a match; however, the well-being score showed some evidence of recovery in both Study 1 (long timescale) and Study 2 (short timescale). Data for a female football player.

of baseline testing. Some jump variables showed evidence of a change immediately after a match (Figure 1), but the changes were not substantial. The recovery data in both Study 1 (long timescale) and Study 2 (short timescale) did not show clear evidence of recovery after a match (Figure 1). Any patterns in the loess fits are probably random fluctuations rather than true trends in the data. For the exponential curve fits to the recovery data, the time constant was a few hours but these values are not reliable because the 95% confidence interval was greater than the observed value. The plateau values in the exponential curve fits were similar to the mean values obtained in the baseline testing. The well-being score showed some evidence of a decrease immediately after a match and a gradual recovery over the following 2–4 days (Figure 1).

DISCUSSION: The results from this study do not support the two initial hypotheses. Although the jump variables were reliable, the changes induced by a match were not sufficiently large that the time-course of the recovery of the jump variables in an individual athlete could be detected in the days after a match using either a loess fit or an exponential fit. Therefore, we could not reliably discriminate between the selected jump variables in the magnitude of the time constant and so could not reliably identify one jump variable as a better indicator of full recovery from neuromuscular fatigue than another jump variable.

The results from this study suggest that a well-being questionnaire might be a more reliable method of monitoring the time-course of recovery from fatigue than jump variables obtained from a force platform. The observed trends in the well-being score suggest the matches induced some muscle damage and delayed fatigue in the athlete. However, this delayed fatigue was not evident as changes in the jump variables.

Our results suggest that a typical football match might not be sufficiently strenuous as to induce delayed fatigue that can be readily detected using jump variables. In many high-performance sport programs the athletes are monitored using one jump session per day and the magnitude of the jump variable is taken as the average of 3–6 jumps. Magnitude-based decisions are then used to identify changes in the jump variable. The present study used a much more intensive method of monitoring the athlete (three and eight jump sessions per day), and curve fitting was used to quantify the rate of recovery. However, no evidence of recovery was detected in the selected jump variables. Our results suggest that previous reports of changes in jump variables in the daily test sessions after a football match might be just random fluctuations rather than a true response to the match.

We investigated the sensitivity of our approach of fitting an exponential curve to recovery data by using a mathematical model to produce sets of simulated recovery data. We found that even with eight test sessions per day in the two days after a match, the signal to noise ratio needed to be greater than 3 to be able to detect a time constant of 6 hours (the expected value). That is, if the coefficient of variation in the jump variable is 5% (a typical value), the initial change in the jump variable arising from the match needed to be greater than 15%. A football match might not be sufficiently taxing to induce a change of this magnitude. Such large changes in jump variables might only be produced by very strenuous bouts of eccentric exercise such as a downhill running race.

CONCLUSION: For the player in this study the time-course of recovery from a football match was too small to detect using the selected countermovement jump variables.

REFERENCES

Gathercole, R., Sporer, B., Stellingwerff T. & Sleivert G. (2015). Alternative countermovement jump analysis to quantify acute neuromuscular fatigue. *International Journal of Sports Physiology and Performance,* 10, 84–92.

Hooper, S.L. & Mackinnon, L.T. (1995). Monitoring overtraining in athletes: Recommendations. *Sports Medicine,* 20, 321-327

Linthorne, N.P. (2001). Analysis of standing vertical jumps using a force platform, *American Journal of Physics*, 69, 1198-1204.

Linthorne, N.P. (in press). The correlation between jump height and mechanical power in a countermovement jump is artificially inflated, *Sports Biomechanics*.