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Compensatory Inactivity in Female Collegiate Soccer Players

Caylee Costello
South Dakota State University

COMPENSATORY INACTIVITY IN FEMALE COLLEGIATE SOCCER PLAYERS

BY

CAYLEE COSTELLO

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THESIS ACCEPTANCE PAGE

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This thesis is approved as a creditable and independent investigation by a candidate for the master’s degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Matthew Vukovich

Advisor Date

Kendra Kattelmann

Department Head Date

Dean, Graduate School Date

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ABBREVIATIONS

BOD POD	body composition tracking system
Counts	unit of measurement for ActiGraph monitors
GPS	global positioning system
Hz	hertz
LPA	light physical activity
MPA	moderate physical activity
MVPA	moderate to vigorous physical activity
PA	physical activity
RPE	rated perceived exertion
SD	standard deviation
sRPE	session rating of perceived exertion
ST	sedentary time
TL	training load
VO2max	maximum of oxygen volume
VPA	vigorous physical activity

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ABSTRACT

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Objective: To measure the physical activity levels of Division I collegiate female soccer players with the use of accelerometers to help determine compensatory changes and help establish appropriate training rhythms through the course of a season.

Design: 25 female Division I soccer players volunteered to participate in a 7-day observational study. Players wore an ActiGraph GT3X+ accelerometer during waking hours. Five second epochs were recorded and age appropriate physical activity cut points were used to determine the minutes of sedentary time (ST), light physical activity (LPA), moderate physical activity (MPA), vigorous physical activity (VPA) and moderate to vigorous physical activity (MVPA) during each day as well as during practice and outside of practice.

Results: ST was significantly greater during days of no practice compared to all other days of the week. VPA and MVPA were also lowest on non-practice days. LPA showed no significant difference between all days when looking at time spent out of practice. When looking at practice time only, there was no significant difference between practice sessions and ST, LPA, MVPA, and VPA. This resulted in the idea that the coach's perception of the physical demands within a practice session were not significantly apparent.

Conclusion: The use of accelerometers can be used to help measure the activity intensities of soccer athletes throughout the course of a week. Utilizing the

accelerometers for an entire season may provide additional information to be used for designing training programs. With the addition of other technology (heart rate and global positioning system (GPS)), there could be a greater sense of training load experienced for each athlete both on and off the field. Compensatory changes in activity was not observed through the collection of the data in this study.

Table 1. Articles used in conceptualization and design of the study.

References (year)	**Study Design, Training Load**	**Subject Characteristics**	**Statistics**	**Training Load Measure and Outcome variables.**	**Findings**
Akubat et al. (2012)	Prospective cohort study	9 Males, Age (17 ± 1 yrs). Soccer Youth Elite.	Paired t-tests for pre and post vLT, vOBLA, LThr, and OBLAhr. Pearson's product-moment correlations coefficients for training load methods and fitness changes.	Incremental test on a treadmill to determine Hrmax. Modified lactate threshold test. RPE Heart rate monitors - Polar Banister's TRIMP	Individualized iTRIMP related better than other methods to change vLT in professional youth soccer There were no significant changes in vLT (p=0.54), vOBLA (p=0.16), LThr (p=0.51) and OBLAhr (p=0.63) Banister's TRIMP significantly correlated with session-RPE (r=0.75; p=0.02) and Team TRIMP (r=0.92; p<0.001)
Alexiou and Coutts (2008)	Observational correlation study	15 Females, Age (19.3 ± 2 yrs). Soccer Elite.	Pearson's product-moment correlation for relationship between session-RPE and HR-based monitoring. One-way ANOVA with a Scheffe post hoc test used for differences of mean TL for the comparison of each exercise.	Session-RPE (CR-10:RPE) Internal TL (HR using Polar monitors) TRIMP V_{O2max} Lactate threshold (LT_{zone})	Correlation of session-RPE and HR-based TL methods showed a significant correlation p<.01 Correlation for session-RPE TL and 3 HR-based showed significance (p<0.05) Strongest correlations were technical (r=0.61 - 0.79), conditioning (r=0.60 - 0.79), speed (r=0.61 - 0.79)
Algroy et al. (2011)	Cross sectional experimental	15 Males, Age (24 ± 5 yrs). Soccer, Norwegian Professional	Repeated-measures ANOVA was used for HR and RPE intensity zones	Treadmill gas-exchange test to determine ventilatory threshold Maximal oxygen consumption (VO2max) Heart rate - Polar s610 sRPE	Preseason findings: 73% at HR < VT1, 18% VT1 <VT2, 9% >VT2 Average training load for preseason = 3577 ± 920 AU in-season findings: 71% <VT1, 21% VT1 < VT2, 8% >VT2 Average training load in-season = 2536 AU
Anderson et al. (2015)	Cross sectional study	12 Males, Age (25 ± 5 yrs). Soccer Elite	Linear mixed models were used, Tukey post-hoc pairwise comparisons were	GPS (Viper pod 2) Video analysis using computerized semi-	Accumulated activity was higher in a 2 game wk compared to 1 game (50 min, ES=1.7, p<0.001) and 3 game wk (35

		English Premier League	used to find differences between days or weeks. Standardized pairwise differences were calculated to determine effect size. Effect size thresholds are <0.2=trivial, 0.2-0.6=small, 0.7-1.2=moderate, 1.3-2.0=large, >2.0=very large. Statistical analysis was carried out with R, version 3.0.3	automatic video image recognition Standing (0-0.6 $km.h^{-1}$) Walking (0.7-7.1 $km.h^{-1}$) Jogging (7.2-14.3 $km.h^{-1}$) Running (14.4-19.7 $km.h^{-1}$) High-speed running (19.8-25.1 $km.h^{-1}$) Sprinting (>25.1 $km.h^{-1}$)	min, ES=1.2, p<0.01) but no significance between 1 game and 3 game wk (15 min, ES=0.5, p=0.19). Significant differences in distance in speed zone 0-0.6 km.h-1 were present in all wks. Walking distance was higher in both 2 game (2012 m, ES=1.3, p<0.01) and 3 game (1627 m, ES=1.0, p<0.05). Jogging distance higher in 2 game (3642 m, ES=1.6, p<0.01) and 3 game (3881 m, ES=1.7, p<0.01) compared to 1 game wk. Running, high speed running and sprinting distances all showed significant differences (p<0.01) between all wks.
Clemente and Nikolaidis (2016)	Observational	31 Males, Age (20.4-27.2 ± 4.01 yrs) 28 Females, Age (19.3-23.3 ± 2.86 yrs) Football/Futsal, Amateur Portuguese	Two-way MANOVA (followed by one-way ANOVA per factor) to compare %HRmax average, %time in intensity zones. Bonferroni post hoc test was used for comparisons and pairwise differences.	HR (Polar Team Bluetooth technology) Internal load %Hrmax (Yo-Yo Intermittent Recovery Test) Z1 - 50-60% HRmax Z2 - 60-70% HRmax Z3 - 70-80% HRmax Z4 - 80-90% HRmax Z5 - >90% Hrmax	Gender and type of sport had significant effects on the HR variables There were significant correlations between gender and type of sport Football: gender and dependent variable %Hrmax (p=0.001, n^2=0.042), %time in Z2 (p=0.001; n^2=0.054), %time in Z4 (p=0.001; n^2=0.031) and %time in Z5 (p=0.001; n^2=0.053) Male specific: football compared to futsal %HRmax (p=0.001; n^2=0.172) Female specific: %HRmax (p=0.001; n^2=0.040)
Gil-Rey et al. 2015	Observational	14 Males, Age (17.6 ± 0.6 yrs). Soccer, Elite Spanish first division club academy. 14 Males, Age (17.5 ± 0.5 yrs). Soccer, Non-elite	Normality criteria were verified for each variable using the Kolmogorov-Smirnov test. Levene's test of homogeneity of variances was used to verify the variance homogeneity. Standardized mean differences (effect sizes (ES))	CMJ arm swing 5 and 15 m sprints Universite de Montreal endurance test TL measurements included: Session rating of perceived exertion (sRPE)	Elite players had greater total and weekly training volume (ES=5.23; ±1.74, most likely, 0/0/100), sRPEres-TL (ES=1.12; +0.79, very likely, 0/2/97), and sRPEmus-TL (ES=0.99; +0.84, likely, 1/5/94) than non-elite. Individual differences for sRPEres-TL (CV=17% and 22% in elite and non-elite, respectively) and sRPEmus-TL

			and magnitude-based inferences (MBI) were calculated to assess the practical significance of changes. Pearson's product-moment correlation coefficients were used to determine relationships between variables. The data analysis was performed using a modified statistical Excel spreadsheet and SPSS statistical software.	Respiratory (sRPEres) Leg musculature (sRPEmus)	(CV=14% and 25% in elite and non-elite, respectively). Large and positive association was found between training and match volume and change in aerobic fitness (r=0.67; CI (95%): 0.37 to 0.83)
Jeong et al. (2011)	Cross sectional experimental	Pre-season 12 Males, Age (24 ± 3 yrs). In-season 10 Males, Age (25 ± 3 yrs). Soccer, Korean Professional	Student's t-test for independent samples for mean duration, frequency, and physiological loads for pre-season and in-season training periods. Independent t-test for specific types of training.	HR (Polar team) RPE (10-point Borg scale) TL = RPE * duration of session (Borg scale) HRmax (multi-stage beep test)	Pre-season training is more intense than in-season training Avg. pre-season load (HR 124 ± 7 beats/min; TL 4343 ± 329 Borg scale*min)(p<0.05) Avg. in-season load (HR 112 ± 7 beats/min; TL 1703 ± 173 Borg scale*min)(p<0.05) Pre-season time spent in maximum HRzone of 80-100%, 18 ± 2% vs 5 ± 2% in-season (p<0.05)
Little and Williams (2007)	Cross sectional experimental	28 Males, Age (24 ± 5 yrs). Soccer English Professional	Repeated measures analysis of variance and Newman-Keuls post hoc test for differences of physiological responses for training drills. Pearson correlation for HR and RPE responses to drills.	Heart rate - Polar Electro Borg 15-point RPE	HR and RPE differed significantly (p<0.05) between drills 2v2 showed significantly (p<0.05) lower HR response (mean SD: 88.7 ± 1.2% HRmax) than 3v3 (91.2 ± 1.3%) and 4v4 (90.2 ± 1.6%) No significant correlation between HR and RPE responses to drills (r=0.60, p=0.200) HR underestimates the intensity of 2v2 drill
Malone et al. 2015	Cross sectional study	30 Males, Age (25 ± 5 yrs).	Mixed linear modeling was used to analyze data with the	GPS (GPSports SPI Pro X)	Daily training load did not differ during each wk of preseason. Daily total

		Soccer, Elite English Premier League	statistical software R (version 3.0.1). A stepwise procedure was used to select the model of best fit for each data set. Significance was set at p<.05. Tukey post hoc pairwise comparisons were performed to examine between pairs of categories.	HR monitor (Acentas GmBH) RPE post-training	distance covered was 1304 (95% CI 434-2174) m greater in the 1st mesocycle than the 6th during season. %Hrmax values were also greater (3.3%, 1.3-5.4%) in the 3rd mesocycle compared to the 1st. Overall training load was lower on the day before a match throughout the season compared to days 2-5 of the wk.
Mara et al. (2017)	Observational - 7 competitive matches	12 Females, Age (24.5 ± 4.2 yrs). Soccer, Elite Australian National League	one-way ANOVA with Bonferroni post-hoc to compare position groups. T-test to compare 45-minute halves. RMANOVA to compare 15-minute periods.	Optical player tracking system (measures displacement of subjects). Number of high-speed runs at <10 m, 10–20 m, 20–30 m, >30 m. Total distance, high-speed running distance, & spring distance during halves and 15-minute periods.	Players covered more TD in 1st half: mean difference=364 m; p<0.001; d=0.896 Fluctuations in TD (p<0.001; partial n^2=0.494) for HSRD (p<0.001; partial n^2=0.378) were found between 15-min periods No period positional interactions found for 45-min halves for TD or 15-min periods for TD: HSRD (p=0.132, p=0.295) SPRD (p=0.293, p=0.090) # of HSRD differed between positions (p=0.002; partial n^2=0.342) 81-84% of HSRD and 71-78% SPRD done in distance < 10 m HSRD (13.9 ± 4.4s) SPRD (86.5 ± 38.0s) varied according to position (p<0.001; partial n^2=0.409) and match time (p<0.001; partial n^2=0.113-0.310)
McLaren et al. 2017	Single cohort, observational	29 Males, Age (24 3 yrs). Rugby, Professional	Histograms and Q-Q plots used for raw data. Missed effects linear model to compare within-session differences in dRPE and between-session differences of RPE. Multiple linear regression was used to	Session training load (sRPE) Session rating for breathlessness (sRPE-B) Session rating for leg muscle exertion (sRPE-L) Session rating for upper	66-91% variance in sRPE training load within training was explained by the combinations of differential RPE training loads. The strongest association between dRPE training loads and sRPE TL was sRPE-L for HIT, sRPE-B for RHIE, SKCond sRPE-T for speed and skills, and sRPE-

			examine dRPE and its variance in sRPE training load.	body muscle exertion (sRPE-U) Session rating for cognitive/technical demands (sRPE-T)	U for RT. dRPE training load combined to explain 77% of variance in sRPE training load (0.141-0.367). sRPE-L showed the strongest association between dRPE and sRPE training loads.
McLean et al. (2012)	Cross sectional experimental	19 Females, Age (19.9 ± 1.2 yrs). College D1 soccer.	2-way analysis of variance (ANOVA) used for differences throughout the season. 1-way ANOVA described time course changes within groups. Scheffe's post hoc analysis was used if a significant main effect occurred.	RPE P_{MAX} Internal load cycling test (Power Cycle Monark stationary bicycle)	Significantly higher load was completed by starters through in-season training wk Load completed during training was significantly higher for non-starters in wk 1 Load completed during matches showed a higher significance for starters outside of wk 1 P_{MAX} for starters from baseline to wk 10 significantly decreased (92.3 ± 6.0% $p < 0.05$) Starters had lower P_{MAX} during wk 10 (92.3 ± 6 vs 98.1 ± 8.2%, d = -0.98, $p < 0.05$) wk 12 (95.4 ± 7.1 vs 100.8 ± 6.6%, d = -0.91, $p< 0.05$)
Watson et al. (2017)	Prospective cohort study	75 Females, Age (15.5 ± 1.6 yrs), Youth soccer	Spearman correlation coefficients were determined between average daily well-being measures and TL. Wilcoxon rank-sum tests were used for comparisons and Fisher's for frequencies. Effect size: Cohen's d. TL: converted to z-scores. Univariable and Multivariable Poisson regression models were used for predictions of injury and illness.	Likert scale (fatigue, mood, soreness, stress, sleep) Sleep volume in hrs fitfor90.com Internal TL (sRPE)	36 injuries, 52 illnesses Days of injury included: Worse mood (1.24 ± 0.2 vs 1.16 ± 0.1, p=0.012) Higher daily TL (517 ± 138 vs 440 ± 158, p=0.042) Average monthly TL higher preceding days with illness (12 442 ± 409 vs 12627 ± 403, p=0.043) Independent predictors of injury included: Worse daily mood (p=0.011, OR=0.012) Higher daily TL (p<0.001, OR=1.98)

					Higher prior day TL (p=0.040, OR=1.34) Predictors of illness: Weekly TL (p=0.005, OR=1.50) Monthly TL (p=0.007, OR=1.54)
Wrigley et al. (2012)	Observational study. - 2weeks	8 players each from U14, U16, U18 elite jr. soccer teams.	ANOVA 3x2 Design. Age (U14, U16, U18) x Session (Match, Training). Post-hoc: Bonferroni.	Training monitored during training and match play using heart rate and time spent in zones. RPE. Training load calculated as global session RPE x duration.	Training load increased with age. Daily training load varied in U18 vs U16, U14. Time in <50%HRmax and >90%HRmax was lower and higher, respectively, in U18 vs U14. Training intensity was lower vs Game intensity. Age related differences in volume and intensity are evident in elite junior soccer players.

References (year)	**Study Design, Training Load**	**Subject Characteristics**	**Statistics**	**Training Load Measure and Outcome variables.**	**Findings**
Baggett et al. (2008)	Longitudinal study	951 girls 6th grade (2003) 8th grade (2005)	SAS Version 8.02 for statistical analyses Weighted kappa statistics used to assess inactivity and different activity between baseline and follow-up trackings. PROC MIXED calculations used for intraclass correlations between 6th and 8th grade years.	Accelerometer (MTI Actigraph) Tracking for 6 days Previous Day Physical Activity Recall (3DPAR) used for self-reported physical activity and inactivity	Intraclass correlations ranged from 0.17-0.22 for self-report, 0.06-0.23 for 3-day accelerometry, and 0.16-0.33 for 6-day accelerometry. OR for being in the 8th grade highest quintile 3.26 (CI:2.28, 4.67) and in the 6th grade highest quintile 3.64 (CI:2.55, 5.20), compared to those in any other quintile at 6th grade 3.45 (2.42, 4.93) for 6-day accelerometry. OR from self-reported values include: Inactivity - 2.44 (1.66, 3.58) MVPA - 2.63 (1.83, 23.79) VPA - 2.23 (1.54, 3.23)
Baggett et al. (2010)	Observations of two cross	6916 8th grade girls	SAS version 9 statistical analyses	Accelerometer (MTI Actigraph)	Every one MET-minute increase of inactivity showed 3.18 MET minutes less

	sectional samples		was used. General linear mixed models for repeated measures designed to assess associations between total physical activity and physical activity intensity patters	Inactive - 0-50 counts/30s Light activity - 51-1499 counts/30s moderate-to-vigorous activity - >1500 counts/30s	of TPA. (95% CI:-3.19, -3.17) Daily inactivity was also negatively associated with TPA on the following day. MVPA was negatively associated with inactivity the following day. Every minutes of MVPA lead to 1.85 min less of inactivity on the same day. (95% CI:-1.89, -1.82)
Goodman et al. (2011)	Observational	345 children, Age (8-13 yrs).	Between-child analysis: linear regression of MVPA Within-child analyses: two-level random intercept models	Accelerometer (RT3 tri-axial) Travel and activity diary (National Travel Survey diaries)	MVPA was lowest in own home and school lessons (11-13% MVPA). 14-29% of MVPA non-home events and 42-60% MVPA was seen in PE/games, school breaks, active travel and sports. 27% of total weekday MVPA was accounted for by school breaks which provided the longest duration. 1% of LPA spent in a day associated with .06% to .15% decrease of MVPA. compensation was evident that each extra 1% time spent at home predicted a .14% (between-child)/.17% (within-child) increase of proportion of MVPA during the rest of the day. Activity synergy for non-school active travel: extra 1% time spent in non-school active travel predicted .38%/.36% increase in time of MVPA.
Long et al. (2013)	Prospective cohort study	2548 youth, Age (6-19 yrs).	Survey-weighted fixed-effects regression model was fit to estimate impact of change in school-day MVPA on total MVPA weekday.	NHANES questionnaire was answered to gather data on participants demographic characteristics Accelerometer (Actigraph Model 7164)	MVPA in a school day was associated with an increase of total daily MVPA. Each minute added a total of 1.14 minutes (95% CI=1.04, 1.24; p<0.001). No effect of school day MVPA on total MVPA by age, group, gender, race/ethnicity, poverty status, or degree of change in MVPA.

			Fixed-effects regression models were fit predicting total daily accelerometer counts and total counts. A separate fixed-effect regression models fit for total daily MVPA, total MVPA outside of school, total accelerometer counts		
Ridgers et al. (2014)	Prospective cohort study	121 Boys, 127 Girls, Age (8-11 yrs), Recreational	Multilevel analyses using generalized linear latent and mixed models for differences between children with complete and incomplete accelerometry data, and school level.	PA levels (ActiGraph model GT3X+ accelerometer)	Study was looking to compare the "activitystate" hypothesis. Found that on any day, every additional 10 min spent in MVPA associated with 25 min less LPA (P<0.001) and a decrease of 5 min MVPA (P<0.001) the following day. In addition, for every 10 min spent in LPA there was 4.6 min less (P<0.001) of LPA and .9 min less (P=0.001) of MVPA the following day.
Ridgers et al. (2015)	Prospective cohort study	125 Boys, 110 Girls, Age (8-11 yrs)	Multilevel analyses were conducted using generalized linear latent and mixed models to estimate associations between temporally adjacent values and the outcome variables.	Accelerometer (ActivPAL)	10 additional minutes of stepping in a day associated with fewer mins of stepping (9 min; 95% CI:-11.5 to -6.2 min) and standing (15 min, 95% CI:-18.8 to -11.1 min) the next day. > time sitting was associated with < sitting the following period

CHAPTER 1

INTRODUCTION

The physical demands of soccer match play and training have been documented for men. During match play, it is common for players to cover distances of 10-14km, with the majority of the distance considered as low-to-moderate intensity.[1–3] Less than 10% of the total distance covered could be considered high-intensity.[4] The physical demands of training are less defined, but have been documented during a single week and 10-week periods for male elite professional soccer players.[5–7] Monitoring training loads (TL) allows coaches and players the ability to measure training adaptations and to minimize the potential for over-training and injury. In addition to monitoring TL, monitoring recovery or activity level outside of practice may also be important to prevent over-training and injury. The research in TL monitoring is limited, especially in female athletes and the information that is available is anecdotal.

Coaches develop practice schedules with specific goals focusing on conditioning, recovery, and tactics. Monitoring TL during team sports has been a challenge with researchers and coaches utilizing perceived exertion, heart rate monitors, GPS, time-motion analysis, and biochemical, hormonal, and immunological assessments.[7–15] All of these techniques have limitations; reliability, sampling rate, type of task, cost, time, or impractical in an applied environment.[16] Accelerometers are relatively new technology for monitoring athletes TL. The body mounted accelerometers assess frequency, duration and intensity of movement by measuring acceleration and deceleration of the body. An algorithm is utilized to differentiate intensity of physical activity and can be used to measure training load and energy expenditure. [17,18]

The purpose of this study was to utilize accelerometers to measure TL during 7-days of a competitive collegiate soccer season. Accelerometers were worn by the athletes to determine TL and to compare activity levels with the coach's goal of the practice. The accelerometers were also worn during non-practice times to determine if there is any compensatory change in activity associated with practices that were of high intensity. We hypothesized that accelerometers will differentiate the level of intensities of TL as the training cycle changes throughout the week. We also assume that compensatory changes in activity would occur during days of increased training intensity.

CHAPTER 2

METHODS

SUBJECTS

Members of the women's collegiate soccer team were recruited to participate; characteristics are presented in Table 1. After an explanation of the expected procedure, verbal approval was gained from the head coach prior to recruitment. Individuals who consented to participate agreed to follow their typical training regimen, and wear an accelerometer for 7 continuous days of the competitive season. This study was approved by the South Dakota State University Human Subjects Committee.

STUDY DESIGN

Women collegiate soccer players were invited to participate in this observational study involving measures of physical activity (PA) and training intensity during 7-days of the competitive season. Dependent variables were counts or minutes of PA at different intensities from an accelerometer. In addition, body weight, body composition, and performance as measured by the beep-test will be presented. This study did not influence or alter training sessions in any way. Monitoring of athletes began on a Wednesday morning at 0600h and concluded 7-days later, on Tuesday night at 2400h. The soccer team did not practice on Saturday and Monday.

PERFORMANCE TEST

Athletes completed a 20m Shuttle run (Beep Test) to determine aerobic fitness. The test involved running continuously between two points that are 20 m apart. These runs were synchronized with a pre-recorded audio which played beeps at set intervals. As the test proceeded, the time interval between each successive beep decreased, forcing the athlete to increase their speed over the course of the test, until it was more difficult to keep in sync with the recording. If the person being tested did not make the next interval, then the most recent level they completed was their final score (two missed shuttles). The recording was structured into 21 'levels', each of which lasted around 62 seconds. Usually, the interval of beeps is calculated as requiring a speed at the start of 8.5 km/h, increasing by 0.5 km/h with each level thereafter. The progression from one level to the next is signaled by 3 quick beeps. The highest level attained before failing to keep up is recorded as the score for that test.

BODY COMPOSITION

Weight and body composition were measured using the BOD POD. The subjects arrived in a bathing suit or Lycra (compression) shorts, and their body weight was recorded. The subject then entered and sat inside the BOD POD and remained there for approximately five minutes. Complete testing took about 10 minutes. The BOD POD measured the air displaced by the subject's body while inside the chamber. Through air-displacement plethysmography, the BOD POD was able to generate results that included: percent body fat, percent body lean mass, fat mass (kg), lean mass (kg), and body density (kg/L). Height was measured using a stadiometer to the nearest centimeter.

ACTIVITY MONITORING

Training intensity, PA and ST were assessed via accelerometer (ActiGraph GT3X+) in both groups. The GTX3+ is a triaxial accelerometer, which senses acceleration in three anatomical planes: vertical (x), anterioposterior (y) and mediolateral (z). The accelerometers were initialized to collect raw data for 7 days at a sample rate of 30 Hz using ActiLife software (ActiGraph, Pensacola, FL). Following the week of participant wear, monitors were downloaded using ActiLife, an epoch length of 5 seconds. Data was further processed using SAS (version 9.3, SAS Institute, Cary, NC). Accelerometer data was first filtered to remove participants who did not meet compliance standards of wear time. Compliance standards required athletes to wear the accelerometer during each day. A day was considered valid if the subject had a minimum of 10 hours of wear time during waking hours.

One day consisted of 18 waking hours, which occurred from 0600h to 2400. Age appropriate PA cut points were used to determine the minutes of ST, LPA, MPA, VPA and MVPA during each day. Minutes of activity in each category were also determined for each practice session as well as time outside of practice. Troiano (2008) cut points were linearly scaled to accommodate the 5 second epochs: ST (0-8), LPA (9-168), MPA (169-499), and VPA (500+).

CALCULATIONS AND STATISTICS

Data were analyzed with a one-way analysis of variance across days of testing. Activity counts for each category were analyzed throughout the entire day, within practice and outside of practice and are reported as mean counts per minute ± SD. Additionally, activity counts were averaged among practice days and non-practice days and then compared to determine if athletes altered activity levels when they did not have practice. These data were standardized to activity in minutes per hour ± SD. When a significant F-ratio was calculated a Tukey-Kramer HSD was used to locate significant differences between days.

CHAPTER 3

RESULTS

Participants included 5 seniors, 5 juniors, 7 sophomores, and 8 freshmen. Subject characteristics of the 25 participants are provided in Table 1. Practices were designed to focus on different aspects of training where the coaches provided a description of the goal for each of the practice sessions.

Wednesday - High impact individual and small group training

Thursday - Tactical large group concepts

Friday - Tactical large group concepts

Saturday – no practice

Sunday - Lower impact pregame training with additional functional conditioning at the end

Monday – no practice

Tuesday - High impact individual and small group training

When PA data was analyzed including time during and outside of practice, ST was significantly greater on Monday and Saturday compared to other days of the week due to practice not being held on those two days. On the opposite end of the PA continuum, time spent in VPA and MVPA was least on Monday and Saturday compared to the other days. LPA was greater on Friday compared to Monday. MPA was less on Monday and Saturday compared to Tuesday, Wednesday, and Thursday. MPA was also less on Tuesday and Wednesday compared to Sunday.

Physical activity during the day analyzed without practice showed similar results. ST was greatest on Saturday and Monday. LPA was not different across the days. MPA was lower on Sunday compared to Tuesday and Wednesday. VPA was greatest on Tuesday compared to the other days of the week and MVPA was higher on Saturday and Sunday compared to Tuesday.

During practice times only ST was not different among the days. Interestingly, athletes spent ~40 to ~50 minutes in ST during the roughly 120 minutes of practice time available. There was no difference in LPA and VPA among the days during practice. MPA was greater on Tuesday compared to Friday while MVPA was greater on Tuesday compared to Thursday. The differences in the coach's planned practice schedule are not evident in the accelerometer data.

To determine if differences existed in PA between practice and non-practice days, the means were compared for the two types of days. During the entire day, ST was greater for non-practice days, while LPA, MPA, VPA, and MVPA was greater for practice days. When practice time was eliminated from the analysis MPA, VPA and MVPA was still greater during practice days compared to non-practice days.

CHAPTER 4

DISCUSSION

One purpose of this study was to utilize tri-axial accelerometers to monitor TL during practice and to compare it with the coach's goal of the practice. We observed few differences in the intensity of practice among the days despite the coach having different goals for each day. A secondary purpose was to determine if athletes exhibited compensatory change in activity associated with practices that were of high-intensity. We did not observe an increase in ST of athletes the day before, the day of, or the day after a high-intensity practice. It appears that female collegiate soccer players maintain a consistent level of activity despite the intensity of the practice.

Adaptations to training are based on the overload principle. Both muscle and metabolic systems are stressed through modifications in frequency, intensity, and duration of exercise sessions and training days. Muscle and metabolic systems respond to the stress by adapting, resulting in improvements in strength and endurance. Coaches develop training plans with this principle in mind. An additional variable that needs to be considered by athletes and coaches is recovery or rest to reduce accumulated fatigue. Accumulated fatigue may lead to over-reaching and if unchecked, over-training. McLean et al.[19] and Kraemer et al.[20] reported a decline in power and strength in female and male collegiate soccer players and an increase in fatigue in starters who had higher overall training loads compared to non-starters. Variables which can contribute to movement on the continuum include physiological training status, environmental conditions, and activity outside of practice.[16] Monitoring training load will allow for coaches and athletes to better design programs to optimize the adaptions to training. Our goal was to utilize accelerometers to monitor the training load for one week during the middle of the competitive soccer season for female athletes. This is the first study to utilize accelerometers to monitor training load in female soccer players. During the week of observation, coaches designed a training program that focused on tactics, low impact, or high-impact. We observed small differences between practices in the amount of time spent at various intensities based on accelerometer cut points; Tuesday's practice measured higher MPA than Friday's practice and higher MVPA than Thursday's practice. Based on our results, the daily training program designed by the coach did not differentiate intensity. In addition, the time spent inactive was quite large (on average about 45 minutes) and does not reflect an efficient use of the limited time the coach has with the athletes.

The attempt to quantify training load has been investigated utilizing multiple strategies, including heart rate, ratings of perceived exertion (RPE), GPS, blood lactate measurements, and/or a combination of the above[9,15,21,22]. The majority of work has investigated the use of session-rating of perceived exertion (sRPE) values as a measure of internal training load. The sRPE was developed by Foster et al.[23] and is calculated as the RPE (Borg 1-10 scale) multiplied by duration of training or match play. Those that have investigated the use of sRPE to quantify TL have reported that it is useful in differentiating among practices designed to focus on tactics, low-impact or high-impact training. [10,14,24–26] Alexiou et al.[27] reported that sRPE was highly correlated with three different heart rate based methods to monitor TL. In addition, Watson et al.[28] reported that higher acute TL measured by sRPE was associated with increased injury risk among female adolescent soccer players, while chronically elevated sRPE was associated with increased risk of illness. A limitation to sRPE may be in its unreliability in detecting TL associated with short bouts of intermittent running.[26] Despite this limitation, Scott et al.[26] still reports that sRPE is valid to quantify TL in intermittent high-intensity team sports.

Heart rate has been utilized in a number of studies to track TL in female and male soccer players.[10,12,27] In these studies, heart rate (HR) zones were established utilizing a laboratory treadmill test to determine maximal HR or lactate threshold. Limitations to utilizing HR to monitor TL exist. Algroy et al.[10] reported equal distribution of time in HR zones despite different goals for the day; similar to our results. They argued that utilizing time in zones is misleading as the time spent in warm up, cool down, and breaks during the training session pulls down the average and does not reflect the high intensity work periods characteristic of soccer practices and match play. In addition, the use of HR zones associated with lactate threshold would require additional testing as the threshold may shift with training.

GPS units have also been investigated to track TL, with equivocal results. Precision of GPS units is dependent upon availability of satellites and if used inside require local positioning systems. Buchheit and Simpson[29] have identified additional limitations: large between-unit variations (up to 50%), validity of distance and speed decrease as acceleration increases, differing signal filtering techniques, software and chipset updates among companies makes historical databases impossible to maintain.

While the use of accelerometers to monitor TL seems promising, more research will be needed to determine the ability to detect differences in TL longitudinally. Accelerometers provide information pertaining to speed, change of direction, orientation, and contacts between athletes in epochs, yet they do not provide that information relative to training status or fitness. Athlete activity during practice is more reflective of tactical issues (rules, play, and coaches' interventions) than fitness status. Thus, activity related variables alone may not be relevant for monitoring TL.

The secondary purpose of this study was to determine if higher intensity practice resulted in compensatory increases in ST during the day or subsequent days. To the best of our knowledge, this is the first to investigate compensatory PA in athletes. We did not observe any differences in ST during practice days. There was more ST on non-practice days, but this was not influenced by the previous day's practice and may be due to the lack of differences in intensity among the days of practice. Previous research has shown that older adults who participate in an exercise program experience an increase in exercise energy expenditure and training adaptions. However total daily energy expenditure remains unchanged due to a compensatory decrease in non-training physical activity. [30–32] Similarly, children and adolescents who experience increases in MVPA on any given day will exhibit less MVPA the following day. [33,34] Interestingly, children who experience an increase in sitting time on one day will exhibit a decrease in sitting time the next day.[35] However, this finding is not universal, Goodman et al.[36] and Long et al.[37] reported that higher MVPA during the school day was not associated with activity compensation at other times. Rather MVPA simply displaced inactivity.[38] The differences in age of subjects, the time of year the data was collected, or the difference in subject characteristics may account for the discrepancies.

The limitations of the study are primarily related to the activity cutoffs that were utilized. Research utilizing commercially available accelerometer/GPS units do not share activity cutoffs as the algorithms developed by the companies are considered proprietary.

We utilized cutoffs associated with measuring PA in the normal population and further research may develop sport specific cutoffs that may be more appropriate to use during practice. However, measuring inactivity during practice or outside of practice will not change. A second limitation is the placement of the accelerometer at the hip. Commercially available sport activity monitors are placed in a vest or sportsbra on the back of the individual to avoid interference with the sport. Schall et al.[39] reported differences in the measurement of PA of individuals from four different locations (right and left arms, trunk, and waist). Schall et al.[39] concluded that PA counts may not agree between the trunk and waist. The trunk may provide a more representative estimate of PA for demanding work tasks. Finally, the current study provided a snap shot of one week out of the 14-week season. A continuous monitoring of practice intensity may provide a different picture regarding coach's goals for practice and the actual activity or intensity measured.

In conclusion, the results of the study suggest training intensity as measured by accelerometers did not differ among the days measured, despite the coaches attempt to implement training programs focused on different objectives. As mentioned earlier, the use of accelerometers alone may not provide enough detail to monitor TL. A system-based approach which includes multiple methods of measuring TL, especially heart rate and possibly perceptions of fatigue, incorporated into a data management system that is able to track multiple measures will be needed to provide meaningful data. In addition, compensatory change in activity during the day outside of practice did not occur following days off of training.

Table 2. Subject characteristics

Age, yrs	19.3 ± 1.2
Height, cm	162.8 ± 3.1
Weight, kg	63.4 ± 8.4
Lean mass, kg	48.9 ± 4.9
Fat, kg	14.5 ± 5.1
Fat, percent	22.4 ± 5.3
Beep Test, level, stage	9.8 ± 1.7
Estimated VO2max, ml/kg/min	46.7 ± 5.8
Vertical Jump	52.3 ± 6.3
10-yard sprint, seconds	1.75 ± 0.10
20-yard sprint, seconds	3.04 ± 0.12

Table 3. Total minutes within each category of activity for each day of the week.

	ST	LPA	MPA	VPA	MVPA
Wednesday	853.2 ±41.0^{ab}	118.5 ±27.7	91.3 ± 28.7	16.9 ± 7.1	108.2 ± 30.3
Thursday	876.1 ±34.5a	110.4 ±22.2	79.6 ± 21.3	13.8 ± 5.8	93.4 ± 22.2
Friday	849.9 ±58.3^{ab}	136.9 ±58.8	77.7 ± 12.3	15.4 ± 7.4	93.2 ± 13.2
Saturday	917.0 ±75.7	123.4 ±78.7	37.9 ± 24.9	1.6 ± 1.5	39.5 ± 25.0
Sunday	882.8 ±45.1	116.9 ±28.9	64.1 ± 19.2	16.1 ± 6.1	80.2 ± 20.0
Monday	930.4 ±39.5	92.1 ±24.2	54.4 ± 28.1	3.1 ± 4.3	57.5 ± 28.3
Tuesday	828.7 ±50.0^{ab}	131.4 ±27.7	97.9 ± 33.2	21.9 ± 6.9	119.9 ± 36.3

a, $p<0.001$ from Monday, b, $p<0.001$ from Saturday.

Table 4. Minutes of activity during practice within each category of activity for each day of the week. There was no practice on Saturday and Monday.

	ST	LPA	MPA	VPA	MVPA
Wednesday	47.8 ± 13.2	26.7 ± 4.8	32.0 ± 9.8	14.4 ± 5.8	46.5 ± 13.6
Thursday	51.2 ± 13.2	30.2 ± 5.8	23.1 ± 6.7	11.5 ± 5.6	39.6 ± 10.4
Friday	52.4 ± 18.8	29.5 ± 7.6	27.1 ± 10.2	12.1 ± 6.4	41.4 ± 11.2
Saturday					
Sunday	43.3 ± 5.8	32.1 ± 6.2	32.1 ± 5.2	13.4 ± 5.3	45.5 ± 4.8
Monday					
Tuesday	40.4 ± 9.7	29.5 ± 5.7	35.7 ± 6.6	15.3 ± 6.4	51.1 ± 9.2

Table 5. Minutes of activity outside of practice within each category for each day of the week.

	ST	LPA	MPA	VPA	MVPA
Wednesday	805.4 ± 35.3	91.8 ± 26.4	59.3 ± 24.6	2.5 ± 3.6	61.8 ± 25.4
Thursday	824.9 ± 39.6	80.2 ± 23.8	51.4 ± 23.7	2.3 ± 2.1	53.8 ± 24.6
Friday	797.6 ± 55.7	107.4 ± 58.8	50.7 ± 15.4	3.3 ± 2.2	54.0 ± 15.2
Saturday	917.0 ± 75.7	123.5 ± 78.7	37.9 ± 24.9	1.6 ± 1.5	39.5 ± 25.0
Sunday	839.5 ± 45.9	84.9 ± 29.1	31.9 ± 17.8	2.7 ± 2.3	34.6 ± 19.4
Monday	930.4 ± 39.6	92.1 ± 24.2	54.4 ± 28.1	3.1 ± 4.3	54.5 ± 28.3
Tuesday	788.2 ± 35.3	101.9 ± 25.0	62.2 ± 29.8	6.6 ± 3.2	68.8 ± 31.8

Table 6. Mean of Practice days compared to Mean of non-practice days (minutes per hour). P-values represent difference between non-practice and practice for each level of activity.

	ST	LPA	MPA	VPA	MVPA
All day					
Non-Practice Days	51.4 ± 3.2	5.8 ± 3.1	2.6 ± 1.5	0.1 ± 0.2	2.7 ± 1.5
Practice Days	47.6 ± 2.8*	6.8 ± 2.1*	4.6 ± 1.5*	0.9 ± 0.4*	5.5 ± 1.6*
	p<0.0001	p=0.04	p<0.0001	p<0.0001	p<0.0001
During Practice					
Non-Practice Days					
Practice Days	23.4 ± 6.7	14.6 ± 3.5	15.7 ± 3.8	6.7 ± 2.9	22.5 ± 5.4
Outside of Practice					
Non-Practice Days	50.7 ± 3.0	5.8 ± 3.1	2.6 ± 1.5	0.1 ± 0.2	2.8 ± 1.5
Practice Days	51.4 ± 3.2	5.8 ± 2.3	3.2 ± 1.5	0.2 ± 0.2*	3.4 ± 1.6
			p=0.08	p=0.03	p=0.054

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