vances in Industrial Ergonomics and Safety III
ited by W. Karwowski and J.W. Yates
/lor & Francis, 1991

ELECTROMYOGRAPHY STUDY OF STRESS CAUSED BY HIGH HEELS

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Four muscles were studied electromyographically on six women who stood for one hour in flat shoes and in high heels. The muscles were soleus (calf), rectus femoris (thigh), paraspinals (back) and semispinalis capitis (neck). Subjective comfort was recorded at the same locations as well as the foot. Comfort declined steadily with time. With high heels, foot comfort was lower. For EMG, median frequency was not affected by time or shoes. The low levels of EMG amplitude were not affected by time or shoes. The results are consistent with previous reports of low levels of muscle activity to maintain standing posture.

[TRODUCTION

Reynolds and Lovell (1910) first reported the tendency of lividuals to lean backward when wearing high heels. This idency also was found in the Antioch College studies (Anon, 31) which reported that women who habitually wore high heels l a sway back posture and increased relaxation of the lominal muscles. Schwartz and Health (1959) used X-ray cords to show a progressive shortening of the heel to ball stance as heel height increased. Schwartz et al. (1964) oorted forces on the forepart of the foot increase with creasing heel height. Gollnick et al. (1964) measured ankle l knee joint angles with an electrogoniometer. High heels l no effect on the knee angles but caused an increase in cle angle extension. Ricci and Karpovich (1964) reported aring high heels increased the height of the longitudinal ch at the end of the day while low heels decreased arch ght. Merrifield (1971) reported high heels caused a gnificant decrease in step length and stride length but nimum change in stride width and foot angle. Bendix (1984) oorted that with high heels, lumbar lordosis (forward vature of the lower part of the spine) and forward pelvic :lination decreased. The line of gravity shifted backward extension of the ankle joints and backward shifting of the js and trunk. Opila et al. (1987) reported high heels ised lumbar flattening, a backward tilting pelvis, a gravity, and a posterior displacement of the head and racic spine.

We found only three EMG studies of standing in high heels. majian and Bentzon (1954) reported increased EMG amplitude the gastrocnemius and peroneus longus while wearing high ls. Joseph and Nightingale (1956) studied the EMG in the gh and calf of 21 women wearing high heels. The EMG litude increased in the soleus of 17 women and increased in thigh of 3 women. Joseph (1968) compared the EMG while king in low or high heels; he noted relatively few ferences in the activities of seven muscles.

The purpose of this study was to determine if selected EMG sures could be used as indices of muscle fatigue during nding in both flat shoes and high heels. It was othesized that both EMG amplitude and median EMG frequency ld vary with subject self-reported decreases in physical fort. The utilization of EMG frequency analysis was used ause shifts in the EMG spectrum have been associated with reased muscle fatigue (Lindstrom et al., 1977; De Luca et , 1983; Nanthavanij and Deivanayagam, 1989; Marras, 1990).

HOD

k

Subjects stood for one hour on concrete, wearing either t shoes or high heels. They wore their own shoes. Flat es were running or tennis shoes. High heels had a heel ght of 50 mm or more. They read or talked during the hour. y had to stand within a one meter square area and could not k or step.

jects

The six female engineering students received extra credit a course.

cedure

We recorded EMG with disposable surface electrodes at the k (semispinalis capitis), lower back (paraspinals), thigh ctus femoris) and calf (soleus). These muscles were chosen provide us with a representative sample of various body ts which were hypothesized to become fatigued. A reference ectrode was attached behind the right mastoid process (ear). The site was prepared to ensure a high quality signal by ving of the site (if necessary), cleaning the skin with ohol, and use of electrode gel. A five minute period was d for signal stabilization.

Then the EMG was recorded for 8 s at time 0, 10, 20, 30, , 50 and 60 minutes. Muscle signals were amplified by AC fferential amplifiers (BAK Electronics) before A to D version and storage at a 1 KHz digital sampling rate. A ndstop filter (57 to 62 Hz) was used to reduce 60 cycle gnal interference.

Immediately after each EMG recording, a subjective comfort ting was obtained from the subject using a modified body mfort map (Corlett and Bishop, 1976). Subjective comfort s recorded at each of the four EMG locations as well as the ot. Although the subject voted on a 1-9 scale with 9=very mfortable, the reported vote is normalized to a 0-100 scale r ease of understanding.

Mean EMG amplitude and median frequency were obtained for ch muscle for each sample period. De Luca (1981) commended use of the median frequency (rather than the mean equency). In order to obtain EMG amplitude, linear velopes were developed following full wave rectification and oothing using a 20 ms time constant. The mean amplitude of e 8 s EMG signal was determined using a signal processing ftware package (RC Electronics).

SULTS

ifort vote Figure 1 shows the shoe vs. time effect. There s a steady decline in the comfort vote with time for both e flat and high heeled shoes. Shoes were not a significant riable when all five body locations were combined. When the ta was analyzed by location, there was a significant fference for the foot. The mean vote for the flat shoes of % was significantly more comfortable than the 58% for the gh heels.

G-amplitude In both shoe conditions and all muscles there re low levels of muscle activity. There was no time effect r any of the four muscles. There was a significant shoe fect only for the thigh muscle; the mean amplitude with flat oes of .017 volts was significantly higher than the .008 lts for flat shoes.

G--median frequency. There was no time effect for any of the ur muscles. There also was no shoe effect for any of the ur muscles.

SCUSSION

The comfort vote results showed the expected results (i.e., bjects were less comfortable with increased time). However was surprising that only the foot showed less comfort with gh heels. It had been expected that other parts of the body so would show less comfort with high heels (relative to flat oes).

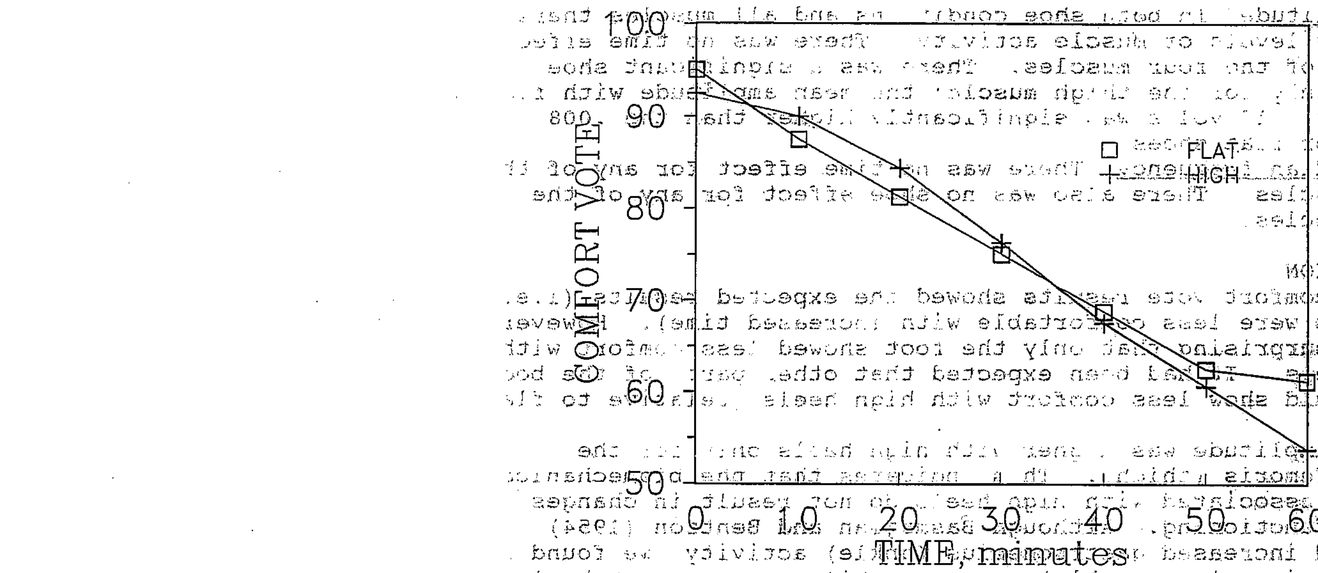
EMG amplitude was higher with high heels only for the ctus femoris (thigh). This indicates that the biomechanical anges associated with high heels do not result in changes in scle functioning. Although Basmajian and Bentzon (1954) ported increased gastrocnemius (ankle) activity, we found no crease in soleus (ankle) activity while wearing high heels. eir finding is somewhat surprising as the gastrocnemius is nsidered a "phasic" muscle which generally functions to oduce relatively rapid changes in ankle angle. The soleus, "tonic" muscle, generally functions to maintain a given kle angle (as during standing posture). Carlsoo (1964), for ample, reported tonic soleus activity during quiet standing.

When wearing high heels, the forward shift of the center of avity (COG) may be countered by increased lumbar lordosis hich would move the COG posteriorly. Thus high heels may ve little net change in the anterior-posterior COG and thus requirement for increased soleus activity.

Our finding that little muscle activity is required for anding is consistent with Basmajian and De Luca's position 985, p.255) that "the muscular activity in standing is ight or moderate." Therefore no muscle fatigue would be pected. This would explain why median EMG frequency did not ange (for any muscle) with time.

Both Lindstrom (1970) and De Luca (1979) say that EMG
pectrum is related to conduction velocity of the muscle fiber
gnal. Muscle fatigue results in the accumulation of
etabolic byproducts, which leads to a slowing in conduction
elocity. This, in turn, results in a lower EMG frequency
pectrum. We found no decline in the EMG frequency
uggesting that muscle fatigue is not related to the increased
scomfort over time of our subjects.

It may be that the discomfort is associated with direct
ressures on the bones and joint capsules and inadequate blood
rculation (Basmajian and De Luca 1985). We previously have
eported prolonged standing increases surface temperature of
e calf and foot (Rys and Konz, 1990). Increases in surface
emperature are related to alternations in blood circulation;
his supports the idea that standing fatigue is related to
actors other than muscle fatigue.



gure 1. Comfort for flat and high heeled shoes as a
nction of time.

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