Activity as a function of body weight

Warren W Tryon, PhD

ABSTRACT  Thirty-one undergraduate men and women who weighed more (overweight) or who weighed less (underweight) than the normal weight limits for their height wore actometers on all four limbs 24 h each day for 14 consecutive days. All groups were found to be equally active. This result fails to replicate previously reported results that overweight men and women are hypoactive. This discrepancy is explained in terms of differences in percent overweight between the present and previous samples. The possibility of a catastrophic decline in activity as a function of percent overweight is discussed.  

KEY WORDS  Activity, actometers, pedometers, obesity, catastrophe

Introduction

Activity as a function of body weight

The relationship between activity and body weight is a complex one (1, 2) obscured by several different activity measures (2). For reasons discussed extensively elsewhere (3), only studies using mechanical devices capable of longitudinal activity measurements in the subject's natural environment will be considered here. Pedometer data (4) demonstrated that a group of 15 obese women walked significantly fewer ($\bar{x} = 2.9$ km/d) than did a matched group of 15 nonobese women ($\bar{x} = 7.24$ km/d). Additional pedometer data (5) replicated this observation in that 15 obese women walked an average of 3.22 km/d whereas 15 matched nonobese women walked an average of 7.88 km/d. These authors (5) reported a similar significant difference for 25 obese men ($\bar{x} = 5.95$ km/d) versus 25 nonobese men ($\bar{x} = 9.65$ km/d).

The purpose of this study is to determine if this tendency for underactivity in overweight persons could be found in a college population where subjects were selected because they exceeded normal weight limits for their height.

Subjects and methods

Subjects

A total of 31 subjects participated in this study. This study was conducted before the new height-weight chart (6) was available. Hence, overweight and underweight were determined by comparing each subject's measured height and weight and estimated frame size (small, medium, large) with the then standard table (7). The height, weight, and frame size of all subjects is reported below to facilitate comparison with the new height-weight chart (6). Percent overweight or underweight was calculated by taking the subject's present weight minus the midpoint of the desired weight favoring longevity (7) and expressing this difference as a percentage of the midpoint value. The weight class midpoint was calculated by adding the lower weight value to the upper weight value and dividing this sum by two. This midpoint is taken as the subject's ideal weight. Calculating percent overweight and underweight in this manner is consistent with previous research (8). The new height-weight chart (6) will reduce the present percent overweight values and augment the present percent underweight values thereby preserving the range of percent overweight studied.

Six overweight ($\bar{x} = 19.88$% overweight; SD = 14.59% overweight) male college students ($\bar{x} = 21.86$ y; SD = 4.49 y) were selected who weighed an average of 24.67 lb (11.19 kg) (SD = 14.90 lb [6.76 kg]) more than the maximum normal weight for their height (7). Seven overweight ($\bar{x} = 17.72$% overweight; SD = 10.03% overweight) female college students ($\bar{x} = 19.86$ y; SD = 1.57 y) were selected who weighed an average of 15.71 lb (7.13 kg) (SD = 11.99 lb [5.44 kg]) more than the maximum normal weight for their height. Although these subjects are not clinically obese, their weight clearly is excessive for their height. Edelman's (9) study of college students used comparably overweight subjects.

Nine underweight ($\bar{x} = -8.87$% overweight; SD = 2.29% overweight) male college students ($\bar{x} = 20.22$ y; SD = 0.83 y) were selected who weighed an average of 6.33 lb (2.87 kg) (SD = 3.74 lb [3.74 kg]) less than the minimum normal weight for their height. Nine underweight ($\bar{x} = -7.93$% overweight; SD = 2.30% overweight) female college students ($\bar{x} = 20.22$ y; SD = 1.39 y) were selected who weighed an average of 4.22 lb (1.91 kg) (SD = 3.27 lb [1.48 kg]) pounds less than the minimum

1 From the Department of Psychology, Fordham University, Bronx, NY.

2 Address reprint requests to Dr Warren W Tryon, Department of Psychology, Fordham University, Bronx, NY 10458.

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normal weight for their height. Edelman's (9) study of college
students used comparably underweight subjects. None of the
underweight subjects was an athlete.

The procedures followed were in accord with the ethical stan-
dards of the Committee on Human Experimentation of Fordham
University.

Apparatus

A Timex Model 108 Motion Recorders (Timex Industries,
Waterbury, CT) was used to measure motor activity of each
subject. This device is a self-winding mechanical wrist watch
that was modified so the self-winding rotor directly drives the
minute hand instead of winding the main spring. Hence, the
subject's activity causes the self-winding rotor to rotate, which
drives the minute hand, which drives the hour hand and calendar
date in the normal manner. Each minute marking on the dial
of the device is termed one activity unit (AU). The apparent
elapsed time, produced by the subject's movements, expressed
in minutes divided by the actual minutes of wearing time yields
activity units per minute (AU/min). Velcro extensions were sewn
to the straps to allow for ankle attachments. It has been shown
(3) that this device is a highly reliable \( r(6) = 0.90-0.99, p < 0.01 \)
measure of the magnitude of mechanically produced move-
ments. The validity of this device is supported by a perfect rank
order correlation between the actometer readings and the inten-
sity of the mechanically produced movements (3).

Procedure

Each subject wore an actometer on each wrist and on each
ankle 24 h/d, except for showering, for 14 consecutive days. To
record their motor activity, subjects were instructed to pull the
stem of the actometer out and rotate the hands until a new date
appeared on the dial; to push the stem back to its original position
and tap the actometer to ensure that it was responding properly;
and to attach the sensor to the prescribed site of attachment.
Each actometer was placed at the same site for the 14-d period.
The subjects then used special data sheets to record the calendar
date, hours, and minutes as indicated on the actometer's dial.
They repeated the procedure for the other three actometers. Fi-
nally, they recorded the real time of day including both hours
and minutes. The subjects then went about their normal daily
routine until the end of the measurement period. At this time
they did as follows: recorded the actual clock time including
both hours and minutes; removed all four actometers keeping
track of which actometer was placed at each site of attachment;
noted the new calendar date, hours, and minutes as indicated
on the actometer's dial; and pulled out the actometer's stem and
rotated the hands until a new date appeared. They observed
whether the hour hand passed the 1200 mark once or twice
before a new date appeared. (This indicated whether the act-
ometer was operating on the PM or AM cycle, respectively.) They
pushed the actometer's stem back to its original position as indi-
cated in the preparatory procedure described above. The sub-
jects then continued with the remaining preparatory steps be-
cause the procedures for preparing to take the readings at the
beginning of a measurement period are substantially the same as
the procedures for taking readings at the end of a measurement
period. Subjects were instructed to take one measurement upon
getting out of bed, another at 1200, a third at 1800, and a final
reading just before getting into bed at night to sleep. The above
description sounds more complex than it is. Subjects essentially
were telling time and resetting a common wrist watch. The con-
siderable common experience college students have with clocks
greatly facilitates understanding this procedure. Nevertheless,
subjects were asked to demonstrate their knowledge of the pro-
cedures before being given data sheets.

Previous research has shown that actometers provide statis-
tically significant and clinically interpretable results in normal
infants, children, and adults; brain-injured children; hyperactive
children; and behavior-disordered children (10). The construct-
ion of actometers makes them respond proportionately to the
magnitude of activity (3). Actometers are attached to the wrist
whereas pedometers are attached to the waist. However, wrists
move during locomotion and this is a primary contributor to
pedometer scores. Wrists also are active while the subject is seated
doing desk work, a common college activity. Pedometers do not
respond to desk-work movements. Hence, it was concluded that
actometers were responsive to a superset of the behaviors to
which pedometers responded thus justifying their use in this study.

Results

Table 1 presents the age, height, weight, frame size, weight
over or under the maximum or minimum weight allowed for the
subject's height based on frame size (7), percent overweight (negative values indicate percent un-
derweight), and the AU/min averaged over the four sites
of attachment and over 14 consecutive 24-h periods, plus
the standard deviation of the 14 daily averages. The mean
and standard deviation for age, pounds (kilograms) over
or under maximum or minimum allowed, and AU/min
also are reported in Table 1.

An analysis of variance (ANOVA) of the data in the AU/min
column revealed a nonsignificant difference for weight
\( F[1,27] = 2.20, \text{ NS} \). The grand mean activity
over all subjects was 25.95 AU/min. The mean for over-
weight men and women (27.84 AU/min) was not signifi-
cantly different from the mean for underweight men and
women (24.59 AU/min). A nonsignificant difference for
sex was also observed \( F[1,27] = 3.38, \text{ NS} \). The mean
for overweight and underweight men (28.00 AU/min) was
not significantly different from the mean for overweight
and underweight women (24.02 AU/min). A nonsignifi-
cant interaction between weight and sex was found
\( F[1,27] = 1.08, \text{ NS} \). The means for overweight men
(28.77 AU/min), overweight women (27.03 AU/min),
underweight men (27.49 AU/min), and underweight
women (21.68 AU/min) were not significantly different
from one another. The major feature of these data is their
impressive homogeneity about the grand mean of all four
groups (25.95 AU/min). Contrary to expectation, the un-
derweight women were somewhat less active (21.79 AU/
min) than the other three groups but this difference was
not sufficient to give rise to a significant weight or sex
effect or a significant weight-by-sex interaction.

An additional test of the major hypothesis that activity is
inversely proportional to weight was performed by cor-
relating each subject's percentage overweight score with the
activity measure. The correlation between percent
overweight or underweight and activity for men was \( r(15) =
0.30 \), which is not significant. The corresponding
correlation for women was \( r(14) = 0.35 \) which also is not
significant. These findings are consistent with previous
data (5). The correlation found by this author in these
previous (5) data between percentage overweight and kilometers walked was r(23) = −0.12 for men and r(13) = −0.03 for women; both correlations are not significant.

These results are particularly compelling given the nature of each data point, which is an average value taken over four sites of attachment (both wrists and ankles), 24 h/d for 14 consecutive days (336 h) while the subjects went about their normal daily routine.

### Discussion

The subjects in this study were clearly of nonnormal weight as they were either above or below the normal weight limits for their height. They were as lean or heavy as the college students previously studied by Edelman (9). The activity measurements were extensive (336 h/subject). The fact that underweight and overweight college men
and women were found to be equally active suggests that one cannot account entirely for differences in weight between these two groups by differences in activity level. To the contrary, Edelman (9) reported a correlation of \( r(88) = -0.22 \) \( (p < 0.05) \) between percent overweight (6) and activity in college students. The smaller degree of relationship was statistically significant because a considerably larger sample was studied.

These data do not contradict previous clinical data (4, 5) because those subjects were all considerably more obese than the overweight subjects studied here. The hypoactive women in one previous clinical study (4) were 62% overweight on average whereas the hypoactive women in another clinical study (5) were 63% overweight on average. The hypoactive men in a previous clinical study (5) were 54% overweight on average. The normally active overweight men in this study were overweight on average by 20% and the normally active overweight women were overweight by 18%. Hence, it appears that men become less active between 20% and 54% overweight. Women appear to become less active between 18% and 62% overweight. This activity decrement may be gradual and linear or it may be a catastrophic step function (11, 12) of percent overweight. A gradual activity decrement seems unlikely given that low and nonsignificant correlations between percent overweight and activity exist from \( -9\% \) to 20% overweight in this study and from \( -54\%\text{ to }140\% \) overweight in a previous study (5). Without knowing the standard deviations for percent overweight and activity in Edelman’s (9) data, the slope of the regression equation presently cannot be calculated thereby preventing one from determining if it is sufficiently negative to predict the low activity levels previously reported for clinically obese persons (4, 5).

Correlation coefficients are directly proportional to the range of the independent variable, percent overweight in this case. Had pedometers been used in this study, a correlation coefficient could have been calculated over both data sets thereby involving a range of \( -9\% \) to 140%. The resulting correlation coefficient would almost certainly be larger than those reported here and very likely would be statistically significant; especially given the combined sample size.

An alternative hypothesis is that a substantial activity decrement rapidly occurs between 20% and 54% overweight for men and 18% and 62% overweight for women. The above combined sample linear regression analysis would not detect a stepwise decrement in activity. The middle portion of the percent overweight spectrum must be studied to determine if a step function is involved. Positive results may be better modeled with catastrophe theory (11, 12) than by linear models.

Another possible interpretation of these results can be offered on the basis of the subject’s age. The subjects in this study were younger as well as less overweight than previous subjects (4, 5). Hence, it could be that younger overweight persons are normally active while older overweight persons are hypoactive. The following studies tend to support this view. It has been reported (13) that 15 overweight 12-y old girls were normally active; as active as 15 age-matched normal-weight girls. The overweight girls were found to walk an average of 11.52 km compared with an average of 12.96 km for the control subjects during their 2-wk stay at a summer camp. The overweight girls were found to walk an average of 8 km while the control subjects walked an average of 9.28 km during their first week home from camp. These differences are not statistically significant. Other investigators (14) reported that 10 overweight 12-y old boys were normally active, as active as 10 age-matched normal-weight boys. The comparison of normally active obese 12-y old boys and girls (13, 14) with hypoactive obese 36-y old men (5) and 42-y old women (4, 5) suggests that age may be the determining factor regarding activity level.

The interpretation that age is an important variable is seriously weakened by Maxfield and Konishi’s report (8) that overweight women whose average age was 41.0 y were as active as normal-weight women whose average age was 42.0 y. Their sample was comparable in age to one sample (5) discussed above where the mean age of obese men was 36.0 y and the mean age of obese women was 42.0 y. These subjects (8) also were comparable in age to the other sample discussed above (4) where the mean age of the obese women was 42.0 y. However, this sample (8) was only 15% overweight, about the same as this sample (overweight men = 21.2%, overweight women = 16.7%) and considerably less overweight than either the Chirico and Stunkard (5) sample (overweight men = 54%, overweight women = 63%) or the Dorris and Stunkard (4) sample (overweight women = 62%). In sum, Maxfield and Konishi’s subjects (8) were as old as Dorris and Stunkard’s (4) and Chirico and Stunkard’s (5) subjects yet they were normally active as were the present subjects. Moreover, Maxfield and Konishi’s (8) subjects were approximately as overweight as the present subjects. It therefore appears that the percent overweight factor is responsible for the reduced activity in the excessively overweight people reported by Dorris and Stunkard (4) and Chirico and Stunkard (5).

In sum, a major contribution of this report is the discovery of a potential range of percent overweight associated with substantial, and possibly rapid, activity decrement. A theoretical consequence of the mathematical model for catastrophic change (11, 12) is hysteresis. The important prediction here is that percent overweight would have to drop below, and maybe considerably below, the point where activity reduction occurred before activity increases result.

References


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