Relationship between Morbidity and Extreme Values of Body Mass Index in Adolescents

AYALA LUSKY,* VITA BARELL,* FLORA LUBIN,** GIORA KAPLAN,* VERONIQUE LAYANI,* ZIPORA SHOHAT,† BOAZ LEV† AND MICHAEL WIENER†


Background. Although the association between overweight and cardiovascular risk factors is well documented in cross-sectional and longitudinal studies, reports of adolescent morbidity associated with underweight in industrialized countries are rare.

Methods. This population-based study includes approximately 110,000 17 year old Israeli Jewish males who underwent routine physical examination at army induction centres. Computerized data tapes include overall health profiles, specification of physical and mental conditions, and height and weight measurements. Medically significant conditions are those with sufficient severity to preclude service in a combat unit.

Results. Functional limitation is more prevalent at both extremes of the body mass index (BMI) distribution: 149.5/1000 among severely underweight individuals and 164.3/1000 among severely overweight subjects. Overweight was associated with hypertension (14.9/1000 among the severely overweight), as well as joint conditions of the lower extremities, mainly hip, ankle and knee disorders. Functional disorders associated with underweight are bronchial and lung conditions, including asthma (14.2 and 18.9/1000 in the mildly and severely underweight), scoliosis, intestinal conditions and emotional disorders (mainly neurosis).

Conclusions. Both under- and overweight are associated with morbidity at age 17. Intervention programmes should begin at an early age.

Keywords: BMI, overweight, underweight, medical conditions, adolescents

Physiological childhood and the growth process tend to end by age 18. Population studies show that weight at this age represents the ideal reference of individual’s weight to be maintained throughout adult life. Overweight, a common disorder among adults in western countries, is often accompanied by significant morbidity, such as hypertension, lipid disturbances, diabetes and osteoarthritis. About 80% of obese male adolescents become obese adults and, as such, have a higher risk of future morbidity and mortality. Hoffman found higher mortality rates for coronary heart disease in adulthood among individuals with a BMI ≥25 at age 18, while the leanest group showed excess cancer mortality. In a longitudinal study, Must showed that overweight in adolescent males was associated with an increased risk of morbidity and mortality from coronary heart disease and colorectal cancer, and it was a better predictor of morbidity than overweight in adulthood.

Most studies which relate intercurrent morbidity and mortality to obesity in childhood and adolescence focus on the association between obesity and cardiovascular risk factors. Obese children are at greater risk for hypertension, total plasma cholesterol, diabetes and orthopaedic conditions. There are only a few reports of morbidity associated with underweight at childhood and adolescence in industrialized societies.

The Israeli male birth cohort of 17 year olds represents an ideal population to provide an estimate of the prevalence of under- and overweight and of related morbidity, based on a nationwide cohort. The data include individual measurements on height, weight, and a wide range of medical conditions, as well as functional status.

The aim of the present study was to determine whether 17 year old Israeli Jewish males with extreme
BMI values have a higher prevalence of functional problems than those within the normal range, and to describe the medical conditions associated with underweight and overweight in this population.

METHODS

Study Population

All Jewish 17 year old males in Israel are assessed for military service and undergo routine physical examination at five regional induction centres, including measurements of height and weight. These draft boards carried out medical examinations of all recruits. Data were analysed separately for each induction centre to evaluate possible confounding between geographical distribution of ethnic groups and regional draft boards. No bias was ascertained.

This study is based on re-analysis of data on approximately 110,000 Jewish Israeli male inductees, only 10% of whom were foreign-born.

Ethnicity was defined by country of origin of the paternal line, i.e. the father's country of birth if foreign-born, or the origin of the paternal grandfather when the father was also Israeli-born. In all, 19 ethnic origin groups were analysed—Bulgaria, Egypt, Ethiopia, Germany, Hungary, India, Iran, Iraq, Libya, Morocco, Poland, Romania, Russia, Syria, Turkey, Tunisia, USA, Yemen and at least three generations Israeli-born. These were re-grouped into three major subgroups according to their BMI distribution:

• Those whose BMI distribution was shifted to the left of the national distribution (the light group—India, Yemen and Ethiopia).

• Ethnic groups whose BMI distribution was shifted to the right of the national distribution (the heavy group—Hungary, Romania, Russia, Libya and Tunisia).

• All other countries whose BMI distribution was similar to the national BMI distribution (the normal group).

Relative Weight

Measurement of weight and height are taken routinely at induction centres. Relative weight was calculated by body mass index (BMI = weight[kg]/height [m^2]).

Inductees were classified into five weight categories according to their ethnic-specific BMI distribution: severe underweight—BMI < 5th percentile; mild underweight—5th ≤ BMI < 15th; normal weight—15th ≤ BMI ≤ 85th percentiles; mild overweight—BMI 85th < BMI ≤ 95th percentile; and severe overweight—BMI > 95th percentile.

Health assessment was based on a standard and systematic clinical examination of each recruit independent of all anamnestic and anthropometric information.

Severity levels for all conditions are pre-defined in a standard code book and the single most severe condition determines the overall level of physical fitness and whether the recruit is qualified for combat or for military service at all. Conditions were considered medically significant if they were of sufficient severity to disqualify the inductee for service in a combat unit. Conditions presented in this study include: hypertension, lower limb problems (knee and hip joint, meniscus and ankle), scoliosis, lung conditions, gastrointestinal disease, and neuroses. Definitions are given in the Appendix.

Statistical Analysis

Prevalence rates (per 1000 individuals) for overall functional limitation and for selected medical conditions were evaluated by the five weight categories. The association between medical conditions and weight was assessed by calculating odds ratios (OR) and 95% confidence intervals (CI).

RESULTS

Extremes of BMI and General Functional Limitation

The overall prevalence of significant functional limitation, i.e. that which prevents assignment to active combat duty, was more prevalent at both extremes of the BMI distribution (Table 1). The functional limitation rate among mildly underweight individuals was 119.5/1000 compared to 103.5/1000 among those with normal weight, while the severely underweight reached a rate of 149.5/1000. Recruits who were mildly overweight had a rate similar to those mildly underweight, while the severely overweight reached a rate of 164.3/1000 (OR = 1.70). All OR were significant at P < 0.05.

Association between Overweight and Specific Medical Conditions

A positive association was found between hypertension and BMI (Figure 1). Recorded prevalence of hypertension increased as BMI increased, and exceeded 5/1000
at BMI of 26. Hypertension by weight categories, as well as other conditions associated with overweight, are presented in Table 2. Prevalence of hypertension was 14.9/1000 severely overweight subjects and 3.2 for the mildly overweight, compared to 1.1 for normal weight individuals (OR = 13.1 and 2.8, respectively). Joint conditions of the lower extremities were also more prevalent among severely and mildly overweight recruits (13.6 and 9.1/1000 respectively) mainly due to hip disorders (OR = 3.9), ankle disorders (OR = 2.3), knee problems (OR = 1.7) and meniscal tears (OR = 2.4, borderline significance).

**Association between Underweight and Specific Medical Conditions**

Functional disorders associated with underweight are presented in Table 3. The most significant functional disorders were bronchial and lung conditions, including asthma. The severely underweight subjects had a prevalence rate of 18.9, compared to 14.2 in the mildly

<table>
<thead>
<tr>
<th>Medical conditions</th>
<th>Weight category</th>
<th>Prevalence (per 1000)</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>Normal</td>
<td>1.1</td>
<td>1.0</td>
<td>-</td>
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<tr>
<td></td>
<td>Mild overweight</td>
<td>3.2</td>
<td>2.8</td>
<td>(1.7–3.9)</td>
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<td></td>
<td>Severe overweight</td>
<td>14.9</td>
<td>13.1</td>
<td>(9.2–17.1)</td>
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<tr>
<td>Lower extremities:</td>
<td>Normal</td>
<td>5.4</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Mild overweight</td>
<td>9.1</td>
<td>1.7</td>
<td>(1.3–2.1)</td>
</tr>
<tr>
<td></td>
<td>Severe overweight</td>
<td>13.6</td>
<td>2.5</td>
<td>(1.9–3.2)</td>
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<tr>
<td>Hip</td>
<td>Normal</td>
<td>0.8</td>
<td>1.0</td>
<td>-</td>
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<tr>
<td></td>
<td>Mild overweight</td>
<td>1.1</td>
<td>1.4</td>
<td>(0.5–2.2)</td>
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<td></td>
<td>Severe overweight</td>
<td>3.1</td>
<td>3.9</td>
<td>(1.8–5.9)</td>
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<tr>
<td>Meniscus</td>
<td>Normal</td>
<td>0.8</td>
<td>1.0</td>
<td>-</td>
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<tr>
<td></td>
<td>Mild overweight</td>
<td>1.0</td>
<td>1.2</td>
<td>(0.4–1.9)</td>
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<td></td>
<td>Severe overweight</td>
<td>2.0</td>
<td>2.4</td>
<td>(0.9–3.9)</td>
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<tr>
<td>Ankle</td>
<td>Normal</td>
<td>1.8</td>
<td>1.0</td>
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<td></td>
<td>Mild overweight</td>
<td>3.2</td>
<td>1.8</td>
<td>(1.1–2.5)</td>
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<tr>
<td></td>
<td>Severe overweight</td>
<td>4.0</td>
<td>2.3</td>
<td>(1.3–3.3)</td>
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<tr>
<td>Knee</td>
<td>Normal</td>
<td>1.5</td>
<td>1.0</td>
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<td></td>
<td>Mild overweight</td>
<td>2.6</td>
<td>1.7</td>
<td>(1.0–2.4)</td>
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<td></td>
<td>Severe overweight</td>
<td>2.6</td>
<td>1.7</td>
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underweight and 10.8 in the normal weight individuals. Scoliosis was also more prevalent among the severely underweight (2.2/1000, borderline significance), as well as chronic intestinal conditions (2.2), mainly coeliac and Crohn’s disease.

Emotional disorders, particularly neuroses, were also associated with underweight. A prevalence rate of 14/1000 among the mild and severely underweight subjects was found, compared to 10.9 among normal weight recruits.

DISCUSSION
This cross-sectional population-based study shows an association between current morbidity and over- or underweight status among male adolescents, and identifies the different health conditions contributing to excess morbidity at each extreme of the BMI scale. The prevalence of pathology among adolescents associated with the entire spectrum of weight has not been previously available.

The BMI has been accepted as the most satisfactory scale of obesity based on weight and height. It is highly correlated with weight and independent of height. However, it cannot distinguish between the contribution to body weight of fat tissue and that of muscle, bone and water. This may introduce bias and cause underestimation of the risk ratios. However, prediction of ponderosity in middle age males from BMI early in life has been shown to be reliable.

Five regional medical draft boards carried out medical examinations of all recruits including evaluation of weight and height. Inter-draft board differences in techniques and results were negligible, and eliminates a possible bias.

In this study, overweight in 17 year old males was significantly associated with intercurrent hypertension and with lower limb joint disorders. Measurement artifacts, such as the use of regular cuffs for obese individuals, might artificially raise blood pressure levels and may have been present. However, ergometric measurement was part of the basic hypertension evaluation, thus reducing the chance of false positive results.

The direction of the association between overweight and joint conditions is unclear. Severely overweight individuals may have an excess burden on joints, thereby worsening existing problems. Conversely, people with painful joint conditions may decrease their physical activity, and hence gain weight.

In this study underweight was found to be associated with excess bronchial conditions, severe scoliosis (borderline significance), neurosis and intestinal malabsorptive disorders. The association between underweight and intestinal disorders found in this study may be a consequence rather than an aetiologial effect.

The higher prevalence of morbidity at extreme weight categories at age 17 shown in this study strengthens the importance of weight and BMI as a readily available marker of morbidity. The identification of extreme values of weight at a young age may enable targeting individuals with potentially severe morbidity which can be successfully prevented, or may ameliorate the effects of current morbidity. Preventive health programmes are often initiated in adulthood, possibly too late in life to reduce the onset of chronic disease. The accumulation of additional risk factors as age increases causes difficulties in preventing the onset of disease. An early marker for morbidity may lead to improved effectiveness of primary as well as secondary prevention.
A number of caveats: In contrast to a standard morbidity survey with research definitions, this study is a standardized mass clinical examination designed to identify combat fitness among military recruits, as well as to identify conditions present prior to recruitment which may be adversely affected by field conditions, and thus prevent inappropriate placement during military service. Several of the reported diseases are based on the individual report of a specific problem, and additional examinations are conducted for confirmation. Underestimation of morbidity may therefore occur among those individuals who fail to report disease (false negatives). However, most conditions are evaluated for each individual. The prevalence reported in this study is based on the medical conditions reported and on judgement of the severity of this condition. In this case a health problem could be considered more serious if the individual was obese as well, which will lead to overestimation of the prevalence of the health conditions. However, health assessment was based on a standard and systematic clinical examination of each recruit, independent of all anamnestic and anthropometric information. Severity levels for all conditions are pre-defined in a standard code book and the single most severe condition determines the overall level of physical fitness and whether the recruit is qualified for combat or for military service at all. In addition, diagnoses are based on clinical examinations, independent of the desire of the inductee to serve in the army. It should be noted that in Israel reluctance to serve in the army is relatively rare, and attempts to simulate morbidity, and thus elude service, are generally identified.

In order to negate the influence of ethnicity on the relationship between BMI and health conditions, each recruit was categorized according to his specific ethnic group BMI distribution. The association between BMI and health conditions held true within each ethnic group.

In conclusion, the strength of this study is that results are based on nationwide cohorts systematically examined, with anthropometric and medical information available, rather than a selected population of 17 year old males. The association between morbidity and overweight at age 17 suggests that intervention programmes developed to prevent or reduce morbidity should be targeted to adolescents and young adults.

REFERENCES

APPENDIX

Definitions of Medical Conditions used in this Study

Hypertension. Measurement of diastolic blood pressure > 95 mmHg or systolic pressure > 150 mmHg, not receiving treatment and with a hypertensive response to ergometry, or hypertension requiring continuous medical treatment.

Knee. Radiological changes and objective physical findings following trauma or surgery to the knee.

Hip joint. Joint changes with limitation of movement in all directions, osteoarthrosis, or following surgery of hip with x-ray changes.

Meniscus. Tear with recurrent clinical symptoms or tear of ligaments affecting joint stability.

Ankle. Following ankle trauma or surgery with movement limitation, recurrent sprain, or arthrodesis of the ankle.

Scoliosis. Only if severe or associated with frequent back pain or respiratory difficulties.

Asthma. Chronic asthma requiring continuous therapy.

Bronchitis. Chronic bronchitis with signs of emphysema.

Neuroses. Including phobia, and obsessive reactive depression.

Overall significant functional limitation. Combination of any medical condition (including all others not mentioned above) which precluded service in a combat unit. The overall Israeli Defense Force fitness profile is set at the most severe score assigned for any condition.