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Growth Patterns and Physical Plasticity in Adolescent Laborers

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A B S T R A C T

Data about the effects of working environment and excessive physical loads on human growth and constitution are insufficient. Although there are a few studies which link growth retardation in children's stature and long bones to their exposure to hard labor, it is difficult to discern whether the detrimental effects of compressive forces on growth result solely from severe compressive stresses or from the subjects' poor economic and substandard nutritional conditions as well. The aim of this study was to clarify this issue by comparing the anthropometric dimensions of laboring and non-laboring adolescents; both groups came from lower socioeconomic strata and were subject to poor living conditions. The laboring group consisted of 532 male apprentices aged 13.5–18.5, and the control group, of their 451 non-laboring peers who were attending school during the period of observation. Body weight, 3 vertical dimensions (stature, upper and lower limb lengths), 2 diameters (elbow and knee breadths), and 3 circumferences (contracted and relaxed upper arm girth and calf girth) were measured. In addition, relative growth according to the body height for each variable was computed, since relative variables are more valuable in evaluating the effects of excessive loading on the human body. The analyses showed that all vertical dimensions of laboring adolescents lagged behind those of their non-laboring peers. There were also clear differences between the two groups with regard to relative diameters and girths. The pressure effects of physical activity stimulate the transversal growth of the long bones. Similarly, circumferences, especially contracted upper arm girth relative to stature, are more developed in the laboring group than in the non-laboring group. These findings suggest that excessive workloads retard adolescents' vertical growth, especially in upper parts of the body, but that they stimulate transversal growth of the long bones and muscle development.

Key words: *physical plasticity, child labor, physical growth, mechanical loading, body proportions*

Introduction

Work is a phenomenon coeval with human history. Nevertheless, even today there is not sufficient information as to how the human body is affected by physical burden and what kind of reactions it gives to such exposure. Knowledge about child laborers, who start work at an earlier age before having completed their growth and development, is even more limited. The main reason for this scarcity of information is the fact that child labor has been eliminated to a great extent in many economically developed countries. »Western« researchers in general and human biology experts in particular have discarded this subject altogether[1]. For instance, one of the most important international projects on human biology and adaptation, the International Biological Programme (IBP), has not initiated any kind of investigation on the effects of child labor on human growth and development, although it carries out a wide range of research on human adaptation. Researchers in economically underdeveloped countries, where the problem of child labor prevails, have attempted to study the subject with their limited resources. However, these studies have not handled the problem thoroughly, as they have been limited to only height and weight variables[2–9]. Another characteristic of such research is the fact that the main focus has been solely on the determination of the nutritional- and/or health status, whereas issues like physical growth or physical plasticity have been ignored in great extent.

Evaluations of research done on child laborers indicate that, in terms of physical growth, they seem to lag behind their peers who do not work. These findings, however, do not answer questions such as how the child-

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-laborers react to physical burden, what parts of their bodies are more affected by it, and what kind of morphological changes happen in their bone and muscle tissues. Malina[10], who has emphasized the limited presence of such research, makes reference to a single study which focused on the bone development of children who are exposed to physical burden. The research in question was done by Kato and Ishiko[11] in mid-1960s in Japan. They selected 116 child laborers out of 4,000 and, by comparing the closure of the long bone epiphyses, determined that child laborers remain shorter than their peers. However, Malina[10] also states that because this study did not examine the socioeconomic levels or nutritional habits of these children, it is difficult to determine whether the shortness of these children is due to physical burden or malnutrition and poor socioeconomic conditions.

Another source of information that can be utilized in understanding how child laborers and adolescent laborers react to physical loading is analyses of individuals who are active in weight-bearing sports. However, when one looks at the literature on this subject, one sees that the studies concentrate mainly on the changes that take place in bone and muscle tissues at a cellular level. Knowledge about how vigorous exercise affects the physical structure and body proportions of children and about the morphological reactions that these children develop is quite insufficient.

The aim of this research project is to provide answers to the questions mentioned above. The first question to be handled is whether there is retardation in the working child's physical growth under heavy working conditions. Secondly, in the case of retardation, the focus will be on what parts of the body any such retardation occurs. Of particular concern is the question whether the weight-bearing legs or the arms are more likely to be affected by physical burden. Another question to be answered is whether work has a greater effect on the body's linear (vertical) or transversal development.

Materials and Methods

Subjects

In order to find answers to the above-stated questions, 532 male apprentices between the ages of 13.5–18.5 who labor in various branches of industry in Ankara, Turkey, were randomly selected. In order to evaluate how and to what extent these adolescent laborers are affected by labor conditions, 451 adolescents of the same age group who do not work and attend school regularly, were included in the study. Table 1 shows the number of the individuals included in the study, according to their ages. It was ensured that the working and non-working adolescents are of the same socioeconomic levels. The details of demographic, economic and cultural characteristics of the working and the control group have been given elsewhere[1,12]. Members of both groups live in Ankara's slums and come from relatively large families with low educational levels. Scrutiny of the two groups' socioeconomic and demographical characteristic reveals that both groups come from almost the same social strata.

TABLE 1
SAMPLE SIZE IN LABORING AND NON-LABORING ADOLESCENTS BY AGE GROUP

Age group (year)	Laboring	Non-laboring
14±	105	93
15±	111	93
16±	104	93
17±	105	86
18±	107	86
Total	532	451

Within the framework of the study, great care was exercised to select the apprentices from amongst those that work in more difficult working conditions. As it can be seen on Table 2, a great majority of (91.7 %) the apprentices work under hard conditions. The remaining 8.3 % work under lighter working conditions, relatively speaking. It should be noted that the latter jobs demand long standing hours.

Apprentices' working hours are another indicator of the heaviness of their working conditions. The apprentices work, on average, for 10.6 hours a day. For some of them, the working hours can be extended to up to 15–16 hours. It must be noted here that the working hours of these children exceeds Turkey's legal provisions, which dictate 8 hours for adults and 7 hours for young laborers, respectively.

The ages of the individuals were calculated by subtracting the birth dates from the date of measurement and on the basis of the decimal age calculation system[13]. Children with unknown or questionable ages were excluded from the study, because physical growth is a function of chronological age. The age groups have been formed from 13.5 to 14.49 years and so on. As a starting, age group 14 has been chosen since it is legally allowed to start at this age.

Anthropometric measurements and ratios

The study contains 9 anthropometric measurements. The first is body weight. The remaining 8 measurements can be classified into three groups: linear (vertical), transversal (diameter) and circumferencial. Thus, the study uses 3 linear (body height or stature, total arm length,

TABLE 2
WORK FIELDS OF THE APPRENTICES

Job	Number	(%)
Car repair	303	56.9
General repair and maintenance	185	34.8
Light works (cook, barber, etc.)	44	8.3
Total	532	100.0

and height of anterior superior iliac spine or lower limb length), 2 diameters (bicondylar humerus or elbow width, and bicondylar femur or knee width) and 3 circumferencial measurements (contracted and relaxed mid-upper arm girth, and calf girth).

All the anthropometric measurements were taken by means of the techniques proposed by the IBP[14]. Lengths and breadths were taken by a Martin type anthropometer; whereas the girth measurements were taken by a tape measure, the accuracy of which had been formerly tested. All figures were recorded in millimeters. Measurements were taken barefoot with minimal clothing, underwear, and trousers. The adolescents' body weight was measured with a digital scale, sensitive to 0.1 kg; and the weights of individual trousers were subtracted from the overall weights[14].

The above-mentioned measurements constitute the absolute variables of the study. Yet, it was necessary to make a recourse to relative or proportional variables in order to discover the effects of the working conditions on the adolescents in detail. In other words, we propose here that referring merely to the elbow breadths of two individuals to conclude that they have similar development patterns may not reflect reality. Therefore, one should also consider separately the body height/elbow breadth ratios of these individuals. Furthermore, if one of the individuals is taller than the other, one cannot claim that both have the same development pattern. Thus, we calculated relative variables, by dividing the absolute measurements, excluding the body weight, by the body height.

Statistical Analyses

All data related to laboring and non-laboring adolescents were evaluated with the Statistical Package for Social Sciences (SPSS, version 11.5). The anthropometric and proportional values of both groups were compared in terms of age range with the help of one-way analysis of variance (ANOVA). $P<0.05$ was established as the significance level.

Results

The average body weights of both the laboring and non-laboring groups are shown in Figure 1. In all age groups, the apprentices lag behind their nonworking peers. However, this difference between the two groups is statistically significant for only the 17 year-old members ($P<0.05$). The weights of the two groups tend to be similar to one another between the ages 14–16. The difference starts to increase after this interval.

The growth curves of body heights of the groups are shown in Figure 2. The data in question shows that labor slows down the individuals' linear development, in terms of total body length. The average stature of the apprentices is always shorter; and the difference between the two groups is generally significant ($P<0.05$–0.001). When closely examined, Figure 2 indicates that the difference in heights is greater than that of the body weights. Furthermore, the pattern of the height difference between the groups is similar to that of weight difference, i.e., while the difference between the earlier age groups is smaller, it tends to increase in later age groups.

The total arm length of the apprentices is shorter than the controls in all age groups (Figure 3), as is the case for stature. However, the proportions of the total arm length to body height indicate that the laboring adolescents tend to have relatively longer arms than their non-laboring peers (Figure 4).

The iliospinal height (or lower limb lengths) of the laboring adolescents are shorter than those of their non-laboring peers in all age groups (Figure 5). The difference between the apprentices and the controls are greater in older age groups. However, the ratio of the iliospinal height/stature of the groups cannot be considered to be

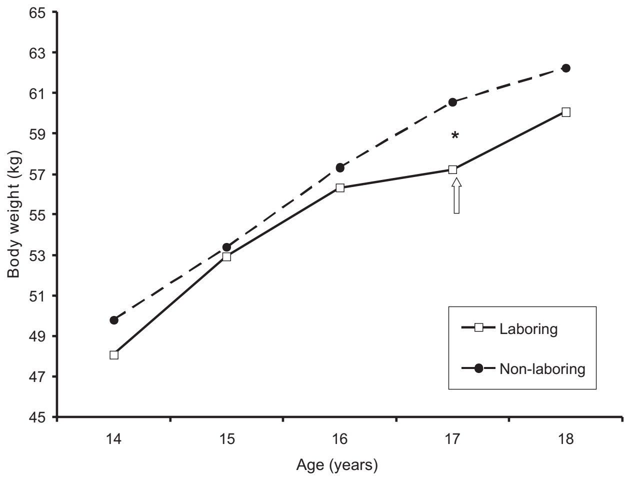

*Fig. 1. Body weight in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05.*

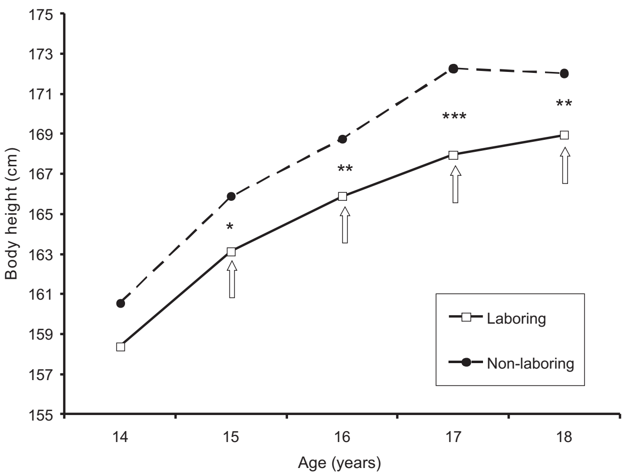

*Fig. 2. Body height in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05, **p<0.01, ***p<0.001.*

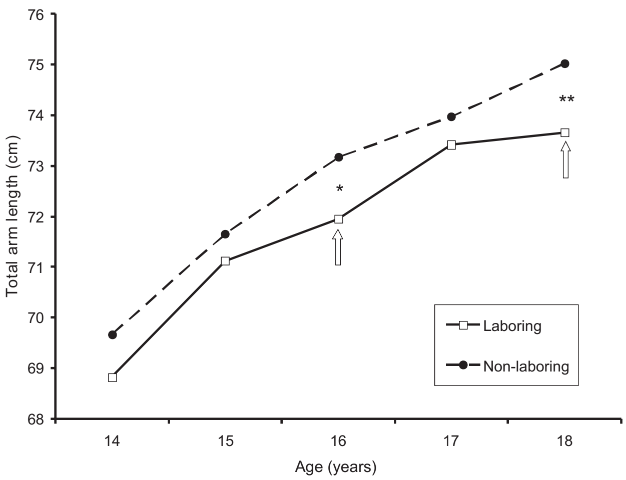

*Fig. 3. Total arm length in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05, **p<0.01.*

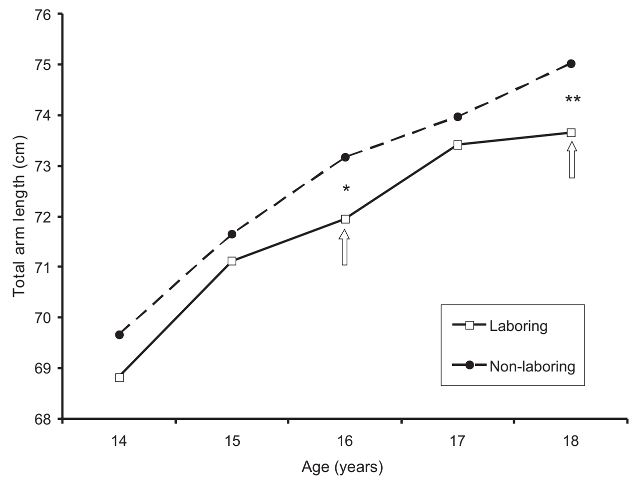

*Fig. 4. Relative total arm length (in relation to stature) in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05, ***p<0.001.*

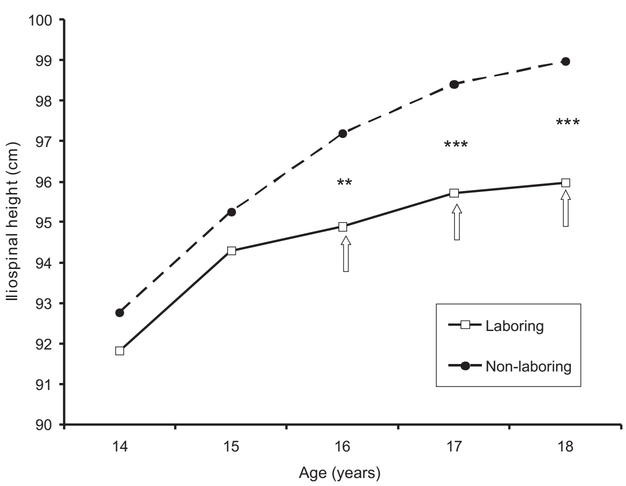

*Fig. 5. Iliospinal height in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, **p<0.01, ***p<0.001.*

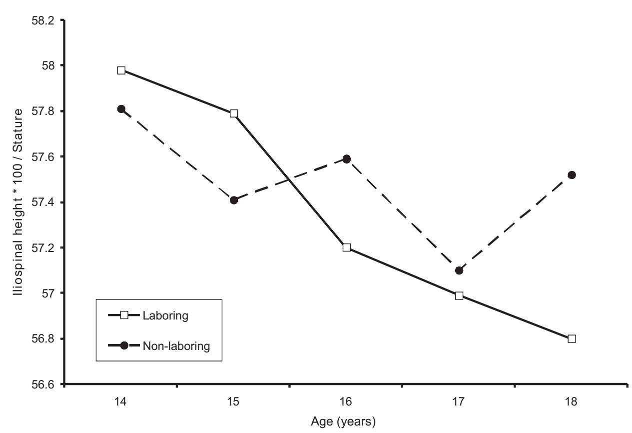

Fig. 6. Relative iliospinal height (in relation to stature) in laboring and non-laboring adolescents.

significant statistically (Figure 6), which indicates the differences in the linear development patterns of the non-burdened upper limbs and of the burdened lower limbs.

As for elbow width, which reflects transversal growth of the long bones of the arm, it can be said that the growth patterns are indicative of greater differences than linear growth configurations (Figure 7). First, it is observed that the laboring adolescents, who have lower absolute linear figures on a regular basis, have larger transverse values of elbow width. Second, the difference between the apprentices and the control groups tends to disappear in the older age groups. This finding is also supported by the univariate F statistics. The relative elbow widths indicate that the transverse development of the apprentices is higher than those of the control group (Figure 8). In other words, the working group members, though having smaller body sizes, are observed to have wider arm bones.

The patterns in the elbow breadth can also be observed in knee breadth. There seems to be no significant difference between the two groups in view of both the knee breadths (Figure 9). However, it is observed that there is a great difference between the laboring and the control groups' knee breadth/stature ratios (Figure 10). The relative knee widths of the laboring adolescents in all age groups are observed to have been higher than those of the control group, which can be considered statistically significant. The data, in other words, indicate that the relative transverse development in the knee zone-which contributes to the bearing of body weight ↑ of the laboring adolescents, is higher.

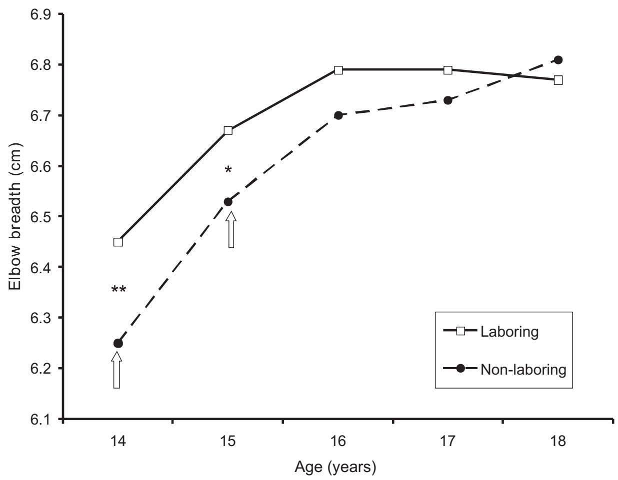

*Fig. 7. Elbow width in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05, **p<0.01.*

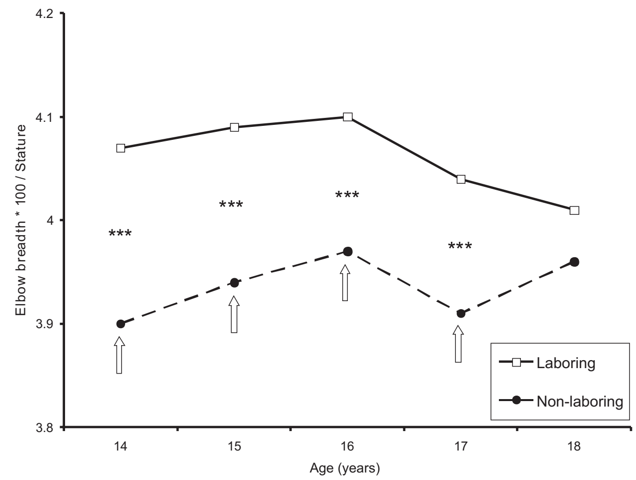

*Fig. 8. Relative elbow width (in relation to stature) in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, ***p<0.001.*

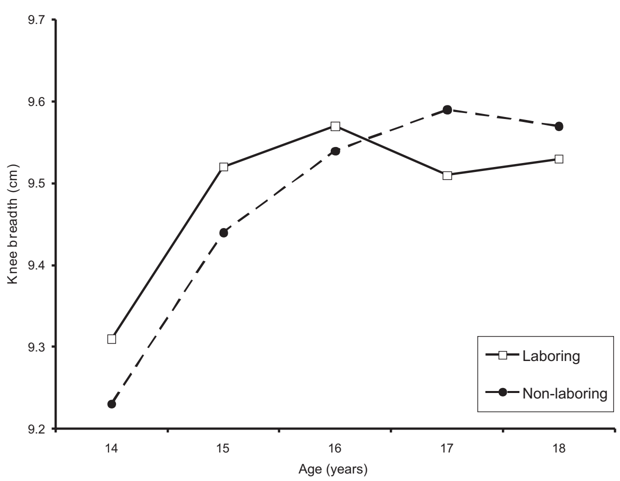

Fig. 9. Knee width in laboring and non-laboring adolescents.

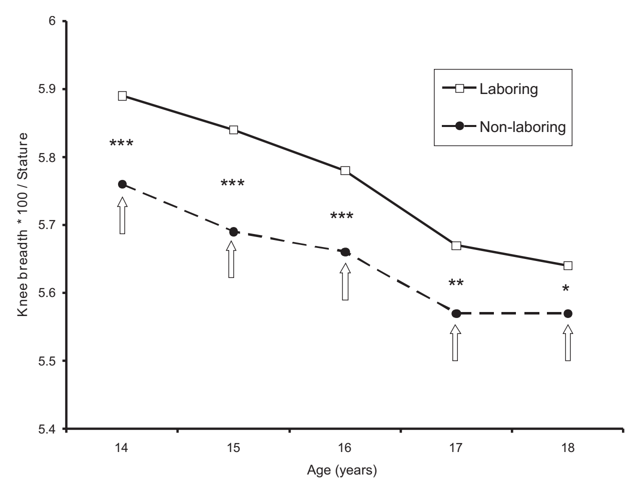

*Fig. 10. Relative knee width (in relation to stature) in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05, **p<0.01, ***p<0.001.*

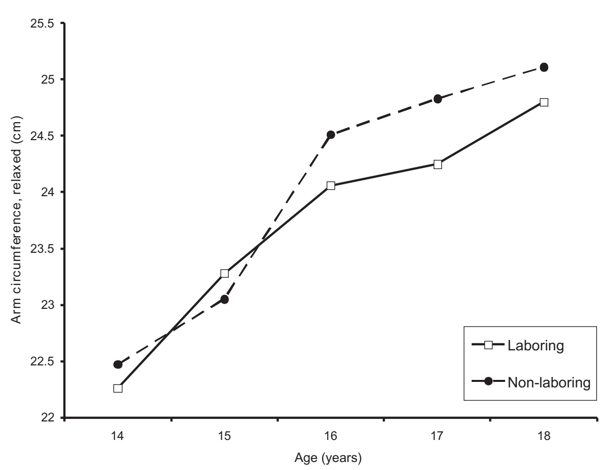

Fig. 11. Mid-upper arm circumference in laboring and non-laboring adolescents.

In order to identify the effects of physical loading on the morphology of muscular tissue, we also focused on circumferential measurements. The average mid-upper arm girth values of the apprentices' and control groups' muscles in relaxed position are given in Figure 11. It can be observed that the growth curves of the groups at the ages of 14–15 do not display any difference; but at older ages, the non-laboring group is observed to have higher values. Yet, the difference between the two groups cannot be said to be statistically significant. Likewise, excluding the age group 15, there seems to be no difference between the two groups in view of the mid-upper arm circumference (relaxed)/body height ratio (Figure 12).

Upper arm circumferences in contracted positions were also taken into consideration in Figure 13. The growth data indicate that both the laboring and the con-

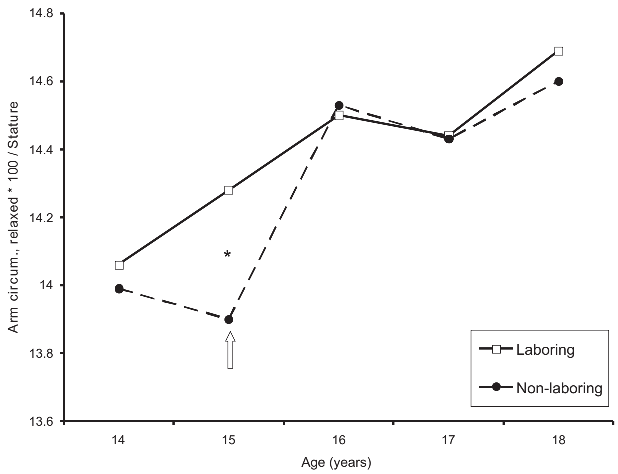

*Fig. 12. Relative mid-upper arm circumference (in relation to stature) in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05.*

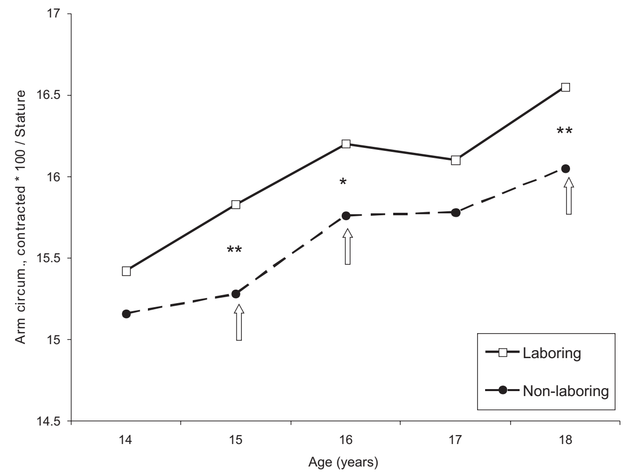

*Fig. 14. Relative contracted upper arm circumference (in relation to stature) in laboring and non-laboring adolescents. – denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05, **p<0.01.*

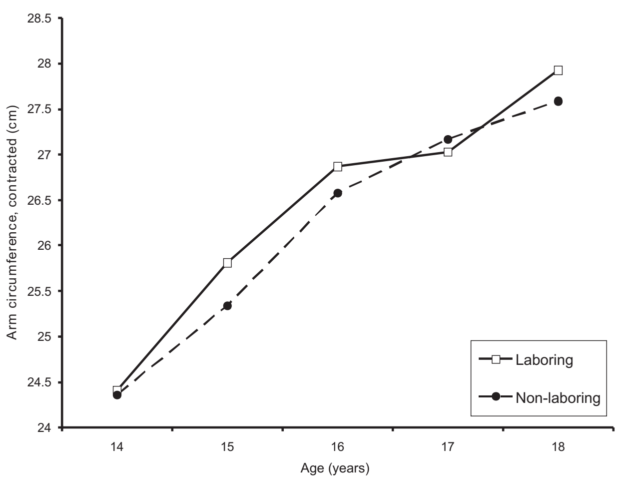

Fig. 13. Contracted upper arm circumference in laboring and non-laboring adolescents.

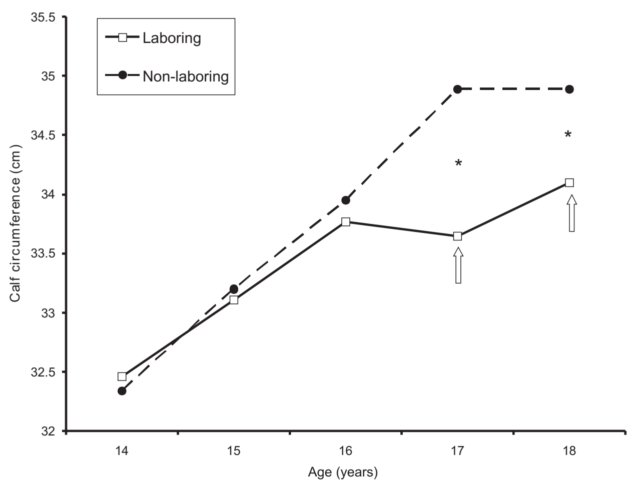

*Fig. 15. Calf circumference in laboring and non-laboring adolescents. ↑ denotes significant difference between the groups obtained using one-way ANOVA, *p<0.05.*

trol groups have almost the same amount of muscle mass. One-way ANOVA tests also point to the fact that there is not a significant difference between the groups. However, in view of the relative upper arm circumference (contracted), we come across completely different phenomena: the apprentices were observed to have ever-expanding muscular volumes in relation to their body heights, when compared to the non-laboring group (Figure 14).

The findings of the calves resemble those of upper arm circumference. Figure 15 indicate that there is not a significant distinction between the groups at ages 14–16; but, the laboring group tends to display retarded growth at later ages. The difference in the last two age groups is statistically significant ($P<0.05$). When the ratios of the calf girth/body heights are considered, the laboring individuals tend to have more developed muscles than their non-laboring peers (Figure 16). But, it must be noted that in the last two age ranges, the mean values of the groups approximate one another.

Discussion

The recently issued reports of the International Labour Office[15] indicate that the number of working children all over the world has reached 351.7 million. The same organization has declared that almost half of the number of working children (170.5 million) are doing extremely risky jobs. These are facts which have long been neglected by anthropologists and human biologists child

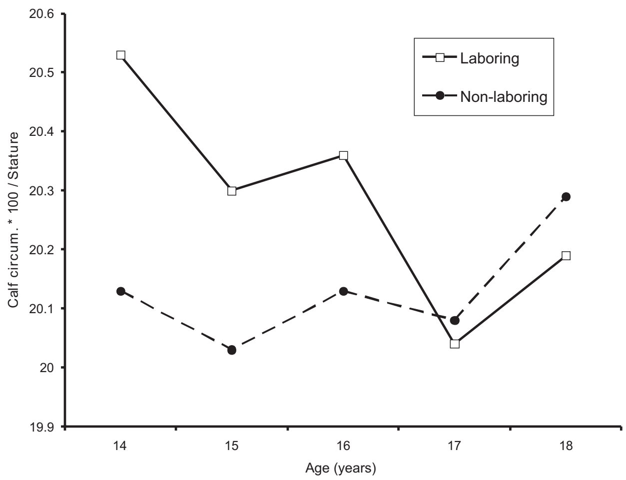

Fig. 16. Relative calf circumference (in relation to stature) in laboring and non-laboring adolescents.

labor is not considered to be a factor hindering physical growth and development. Recent studies indicate, however, that this long neglected issue is urgent and must be addressed by scientists, lawmakers and politicians[1,16].

That labor and physical burden influences growth was a conclusion often drawn by researchers conducting studies[2–7,17–19]. Due to the fact that such studies were usually conducted without control groups, as stated Hawamdeh and Spencer[20], there have been debates about whether physical burden has positive or negative effects on growth. For example, Rosario and Bonga[21], who cite a number of studies on working children, report that some researchers find that the physical development of working children is subject to retardation, while some others publish contrary findings.

The findings of this study indicate that the working adolescents in Ankara are far behind their nonworking peers in terms of both stature and weight. Also, the data show that the difference in stature is much more than that of body weight. Apperantly, excessive hypertrophy in muscle and bone tisseues cause this discrepancy (see below). The account of findings on body height and weight will not be more handled here, since it was handled scrutinously in another studies[1,16].

This study deals instead with the effects of working life on the various parts of the body. Comparative analysis of the upper limbs, which do not bear the body weight, and the lower limbs yields interesting results. In terms of absolute values, the apprentices seem to have short legs and arms. But, in view of the relative variables, the apprentices appear to have longer upper limbs; whereas there is no significant difference between the lower limb lengths of the two groups.

When it comes to the linear development of the long bones of the working children, as also stated by Malina[10], there seems to be no study other than that of Kato and Ishiko[11], whose findings match ours. When Kato and Ishiko's findings and our results are taken together, it can be said that labor and physical burden retard linear growth and change limb proportions in growing children and adolescents, particularly in the upper limb.

Most studies related to this issue have been conducted on athletes, focusing particularly on bone mineral density (BMD) and/or bone mineral count (BMC) rather than on skeletal dimensions. These studies suggest that physical activities may lead to differences in BMC and BMD in several parts of the body. For example, Hamdy et al.[22] examined the regional differences of bone density in various kinds of athletes, and concluded that those who do heavy weightlifting have higher BMC and BMD than those who do not do such exercise. Many other studies which were conducted on people engaging in excessive physical activities at different levels yielded similar results[23–25]. Furthermore, experiments on animals have yielded some findings that indicate that weight-bearing exercises have different effects on the weight-bearing and non-weight-bearing bones[26].

Do labor and exposure to extreme physical burden change the ratios of the parts of the body? Our findings indicate that such conditions do not significantly change the ratio of the lower limb length/body height. Nonetheless, the proportion of total arm length to stature changes considerably among the laboring adolescents. Related literature on this particular topic has been focused on athletes. In a critical review article, Malina[27] claimed that there is no sufficient amount of data verifying the fact that intensive training in sports such as weightlifting, diving, skating and gymnastics leads to shortness and changes in body proportion.

Malina's[27] finding that not much difference exists in the ratios of athletes' body parts can, however, be attributed to the degree of physical burden. It is obvious that the adolescent apprentices in Ankara are exposed to much more heavy physical loading than are athletes, due to the fact that the work they do requires excessive physical effort and that they work six days a week, for often more than 10.5 hours a day. Moreover, there have been investigations showing that excessive physical pressures and burden are detrimental for the bones. For instance, Suominen[28] maintains that intensive endurance training may cause amenorrhea in young women and loss in trabecular bone content. Wohl et al.,[29] similarly posits that excessive exercise can especially be harmful for immature bones. These authors point also that if the individual is subject to malnutrition as well as heavy physical exercise, there will be insufficient remodeling of the bones. Some other researchers have published similar findings[30,31]. Additionally, the potential harmful effects of excessive exercise and loading have been demonstrated in experiments on animals. For example, Wheeler et al.,[32] experimenting with rats, concluded that highly intensive exercise reduces the maximum endurance strength of the bones, and that long-term exercise makes the bones much more brittle. Likewise, Puustjarvi et al.[33] posit that there is a reduction in BMD of the axial skeletons of greyhounds that are forced to run more than their capacities allow.

Our findings indicate that the elbow and knee widths of the apprentices are larger than those of their nonworking peers. This pattern of development is considerably different from the pattern of linear development. As will be remembered, the apprentices displayed lower values in all linear parameters, including stature. The greatness of the apprentices' width measurements indicates that their upper and lower limb bones develop more transversally than they do longitudinally. Especially the relative variables indicate the difference between the groups much more vividly, showing the existence of extremities in the working adolescents. Yet, it must be clarified here that although the apprentices' transversal bone measurements surpass those of their non-laboring peers at earlier ages, the non-laborers' measurements catch up with and even slightly surpass the laborers' at later ages. That the apprentices' bone widths surpass their peers' at earlier ages is probably a result of the instantaneous reaction of their bodies to the hardships of the working conditions.

While there has been little study on the effects of mechanical pressure on bone length development, the number of studies investigating the effects of the same factors on transversal bone development of the bones is high. Various research conducted on animals certifies that the bone densities and widths increase parallel to an increase in physical activity[34,35]. Similar changes occur also in human beings as well. For example, Jones et al.,[36] who compared the active and the passive arms of tennis players, concluded that there is an increase in the width of the cortical tissues of male and female players' active arms, 34.9% and 28.4% respectively. Similarly, Claussen[37] maintains that the elbow bones of rodeo participants become thicker and coarser (hyphertrophy). Later, other studies carried out athletes have been documented the changes of bone architecture and geometry under differential physical loading or unilateral activities[38–40]. In addition, it has been demonstrated that cross-sectional diaphyseal geometry[41,42] and limb articular surfaces[43] are adapted to the mechanical environment.

Both experiments on animals and observations of athletes indicate that actively used bones and bones subject to physical pressures tend to develop excessively. These findings can also be used to explain the changes encountered in the development of working children. Wolff Principles,[44,45] explain why child laborers are short and wide-boned: the linear development (height) of working children, who, in performing incessently monotonous movements all day long, are exposed to heavy physical pressures, is hindered, whereas their transversal development is stimulated by such exposure. Mechanical forces leads to an accumulation of calcium around the bones, particularly in the concave parts[46]. The short but wider limbs of the apprentices can be explained by exposure to pressurizing forces, such as carrying heavy loads, rather than tensile forces.

Circumferences obtained from the extremities, especially the upper extremities of the body are said to reflect the protein-energy reserve of the body[47]. There seems to be no difference between the laboring and non-laboring groups' upper limb girth measurements in the relaxed position, with respect to both absolute and relative values. The question that comes into mind at this moment is whether there is a difference in the amount of subcutaneous fat content of the distinct groups. A detailed account of fat content constitutes the subject matter of another study; but, suffice it to say here that the subcutaneous fat content of the apprentices is lower than the non-laboring group[16,48]. When the body composition parameters of these samples were calculated, it has been seen that laboring adolescents had a lower percentage body fat (BF%) than the non-laboring peers. The data indicate that the laboring group slightly exceeds the control group in muscular content, which in turn shows that the protein-energy reserves of the groups approximate one another.

Upper arm girth measured in the contracted position reflects muscular strength rather than muscular content. That the girths, especially in contracted positions, of laboring adolescents are higher indicates that the apprentices have higher muscular strength. Consequently, we can state that the muscles of the laboring group are subject to a slight hypertrophy, while there is a conspicuous amount of hypertrophy affecting muscular strength.

Despite the fact that there is not much research which focuses on the changes in working children's muscular structure, in sports literature, there seems to be no debate on the nature of any such changes. In other words, related studies in the sports field conclude that regular physical activity leads to increase both in muscular content and muscle strength/endurance, a fact which is also confirmed by[49]. This finding can also be accepted as valid for child and adolescent laborers. However, in this context the question which must be answered is whether working individuals are subject to a significant loss in the content of their muscles, as is true in the case of bones. Some researchers[50] posit that long-term, regular endurance exercise may lead to atrophies in fibers of slow Type I and fast Type IIa. It seems that the findings of this study do not produce the data required to understand whether or not laboring adolescents are also subject to these atrophy types.

Conclusions

The findings of our study indicate that working children's and adolescents' physical growth and development are influenced by working conditions, and that their bodies develop some reactionary responses to mechanical pressures. Working and physical pressure slows down the linear development of the body. This is most clearly observed in the body height of the laboring adolescents who are shorter than their non-laboring peers. The growth pattern of the extremities is a little bit more complicated. While the laboring adolescents' lower and upper extremities are relatively shorter in terms of absolute values, it can be observed that the upper limbs of the apprentices are more developed than those of their non-

-laboring peers and that there is not much significant difference between the groups' lower limb lengths, according to the relative figures.

The effects of working and physical pressures appear to be much greater on the transversal bone development of the body than they are on its linear development. Contrary to the findings on linear development, it is the laboring adolescents who display a higher amount of transversal bone development. Once the relative transversal bone development of the children was examined, it was observed that the apprentices display a higher degree of transversal bone development. In addition, the laboring adolescents were observed to have muscular hypertrophy as well. The high values of the apprentices' relative muscular circumferences in contracted position indicate that their muscular development exceeds those of their non-laboring peers.

All these findings clearly point to the fact that labor is detrimental to the physical development of the children, and that it does indeed change the proportions of the body parts, especially in the upper body. When the number of working children all over the world is duly considered, the need for human biologists in general and auxologists in particular to count child labor among the factors that influence physical development becomes evident. Such knowledge will no doubt enable them to bring the issue to an international platform which will, in turn, take measures to prevent child labor.

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OBRASCI RASTA I FIZIČKE GIPKOSTI KOD ADOLESCENATA KOJI RADE

S A Ž E T A K

Podaci o učincima radne okoline i prekomjernih fizičkih opterećenja na ljudski rast i konstituciju su nedovoljni. Iako postoji nekoliko studija koje povezuju usporavanje rasta dječje stature i dugih kostiju s njihovom izloženošću teškom radu, teško je razaznati da li su štetni učinci usmjerenih snaga na razvoj rezultat isključivo snažnih ciljanih stresova ili i loših ekonomskih i ispod-standardnih prehrambenih uvjeta. Cilj ove studije je bio da razjasni ovo pitanje usporedbom antropometrijskih dimenzija adolescenata koji rade i onih koji ne rade; obje skupine dolaze iz nižeg socioekonomskog sloja i bile su izložene lošim ekonomskim životnim uvjetima. Skupina koja je radila sastojala se od 532 muška naučnika u dobi od 13,5–18,5 godina, a kontrolna skupina od 451 njihovog vršnjaka koji nisu radili i koji su tijekom razdoblja promatranja išli u školu. Provedena su mjerenja tjelesne težine, tri vertikalne dimenzije (rast, duljina gornjih i donjih udova), dvije transverzalne dimenzije (širina lakta i koljena) i tri opsega (obujam stisnute i opuštene nadlaktice te obujam lista). Uz to, izračunat je relativan rast u skladu s visinom tijela za svaku varijablu, obzirom da su relativne varijable vrjednije u procjenjivanju učinaka pretjeranog opterećenja na ljudsko tijelo. Analize su pokazale da su sve vertikalne dimenzije adolescenata koji rade zaostajale za onima njihovih vršnjaka koji nisu radili. Također su postojale jasne razlike između dvije skupine s obzirom na relativna transverzalna mjerenja i obujme. Naši su nalazi ukazivali na to da fizički stresovi različito utječu na gornje i donje dijelove tijela. Fizičke aktivnosti stimuliraju transverzalni rast dugih kostiju. Slično tome, obujmi su, osobito obujam stisnute/stegnute nadlaktice u odnosu na staturu, razvijeniji kod grupe koja radi, nego kod grupe koja ne radi. Ovi nalazi ukazuju na to da pretjerana radna opterećenja usporavaju vertikalni rast adolescenata, osobito u gornjem dijelu tijela, ali da stimuliraju transverzalan rast dugih kostiju i razvitak mišića.