AMBIENT HEAD TEMPERATURE AND FOOTBALL HELMET DESIGN

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15

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ABSTRACT. The heat retention qualities of five different models of football helmets were investigated under four work levels and three environmental conditions. Analysis of data indicated that a significant difference existed among helmets. Further analysis revealed a significant helmet X environmental condition interaction.

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Due to the increasing number of football related head and injuries, considerable attention has been directed to the task of constructing football helmets that will safely absorb severe impacts (2, 4, 5, 6, 9, 11, 12). One means of achieving this objective, safer helmets is to alter the interior design of the helmet. As helmet interior design changes, usually in the form of increasing either the quantity or texture of the impact absorbing material, a secondary problem may develop, the helmet might retain more heat and impair body cooling.

PURPOSE

The purpose of this investigation was to evaluate and compare the heat retention qualities of five different helmets used by the Texas Tech University varsity football team. This

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objective was accomplished by monitoring the temperature within each helmet as subjects performed physical work on a bicycle ergometer under three different environmental conditions. No attempt was made to evaluate the impact absorbing characteristics of the helmets.

PROCEDURES

Subjects. The subjects in this study consisted of thirty male physical education majors attired in T-shirt, sweat pants, tennis shoes and helmet.

Independent Variables. Independent variables considered were helmet design, environmental condition, work level, and replication. Helmets were selected from those used by the Texas Tech University football team and are depicted in Figures 1 through 5 and in Appendix A. The environmental conditions utilized were selected to represent the three levels of heat stress reported by Mathews, et al. (8). These three conditions were catagorized as safe, 23.90 degrees C dry bulb and 40 percent relative humidity; caution, 23.90 degrees C and 65 percent relative humidity; and extreme caution, 29.44 degrees C and 65 percent relative humidity. All environmental conditions were simulated in a 12x15x16 foot environmental chamber, temperature capability range of 5 to 60 degrees C and humidity range of 10 to 98 percent. Work loads of 300, 600, 900, and 1200 kpm were utilized to represent light, medium, heavy, and severe work intensities on the bicycle ergometer. Two replications for each helmet X climatic condition were observed.

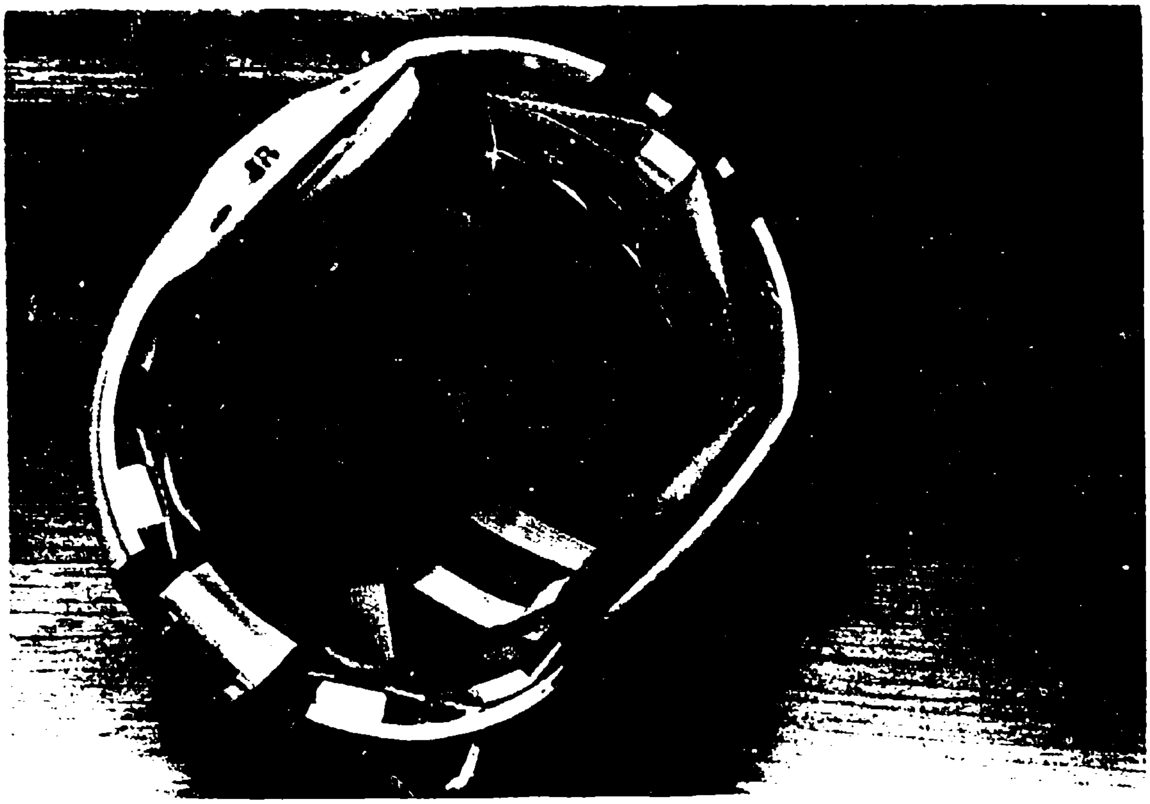

Figure 1. Helmet One

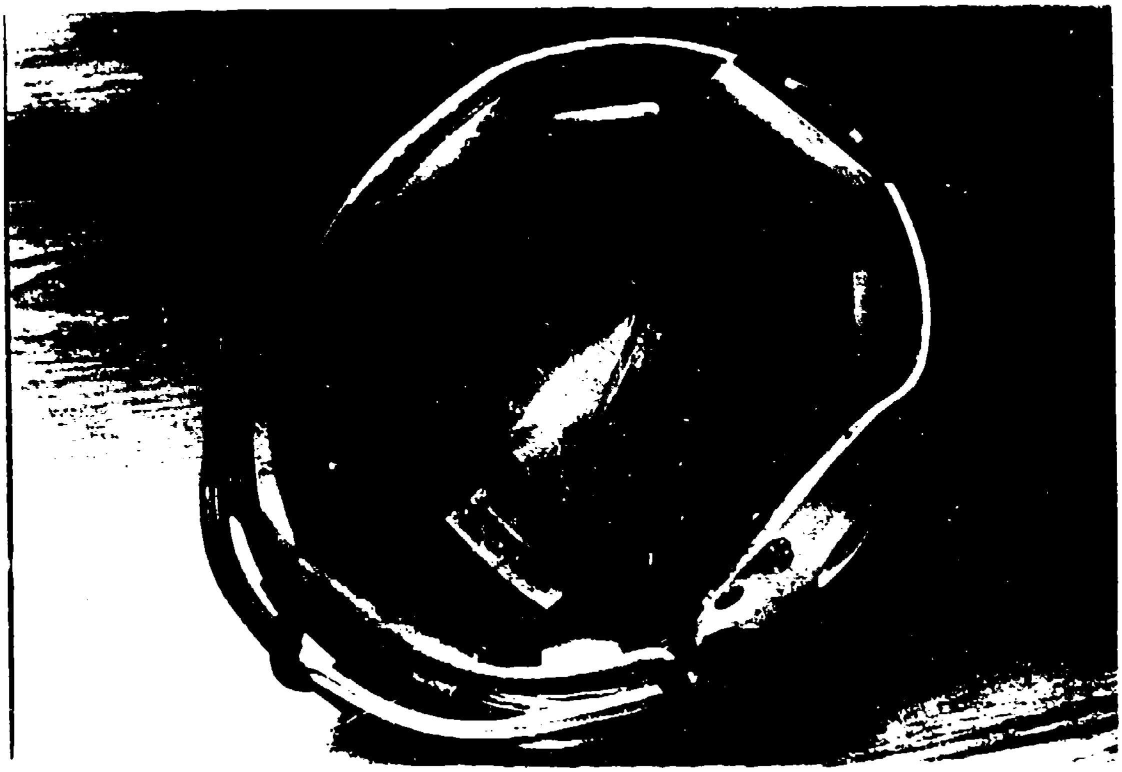

Figure 2. Helmet Two

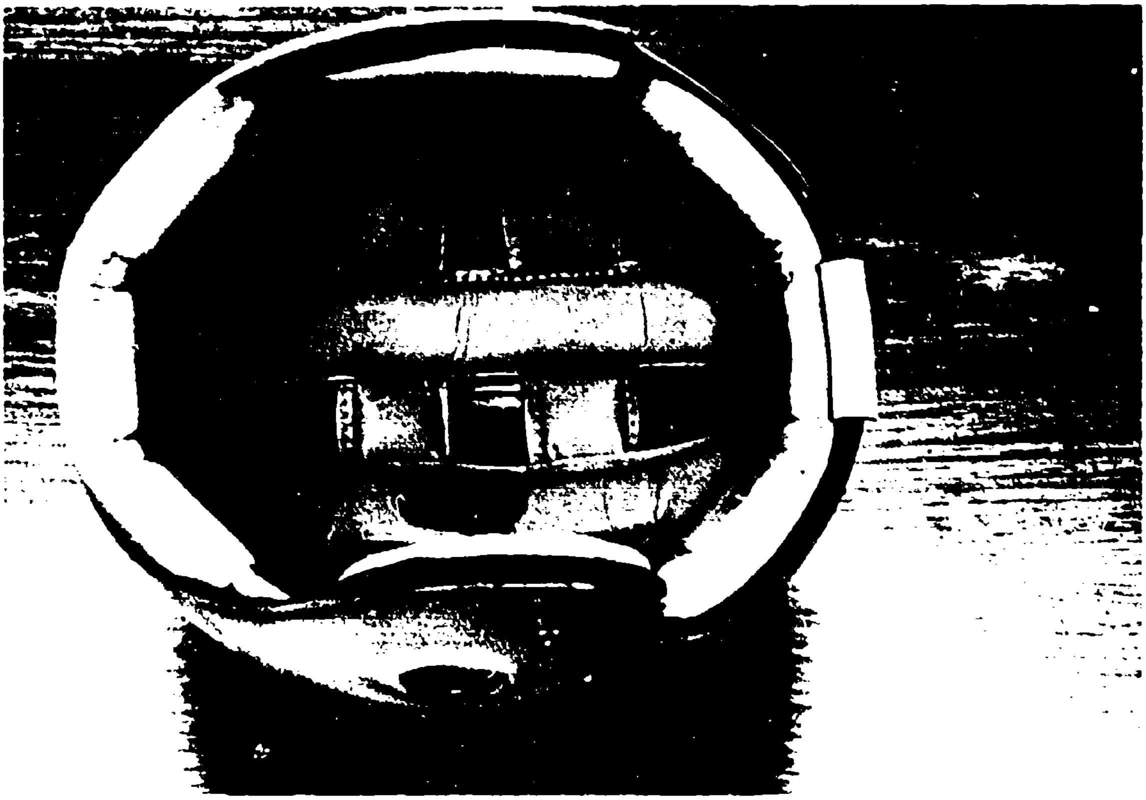

Figure 3. Helmet Three

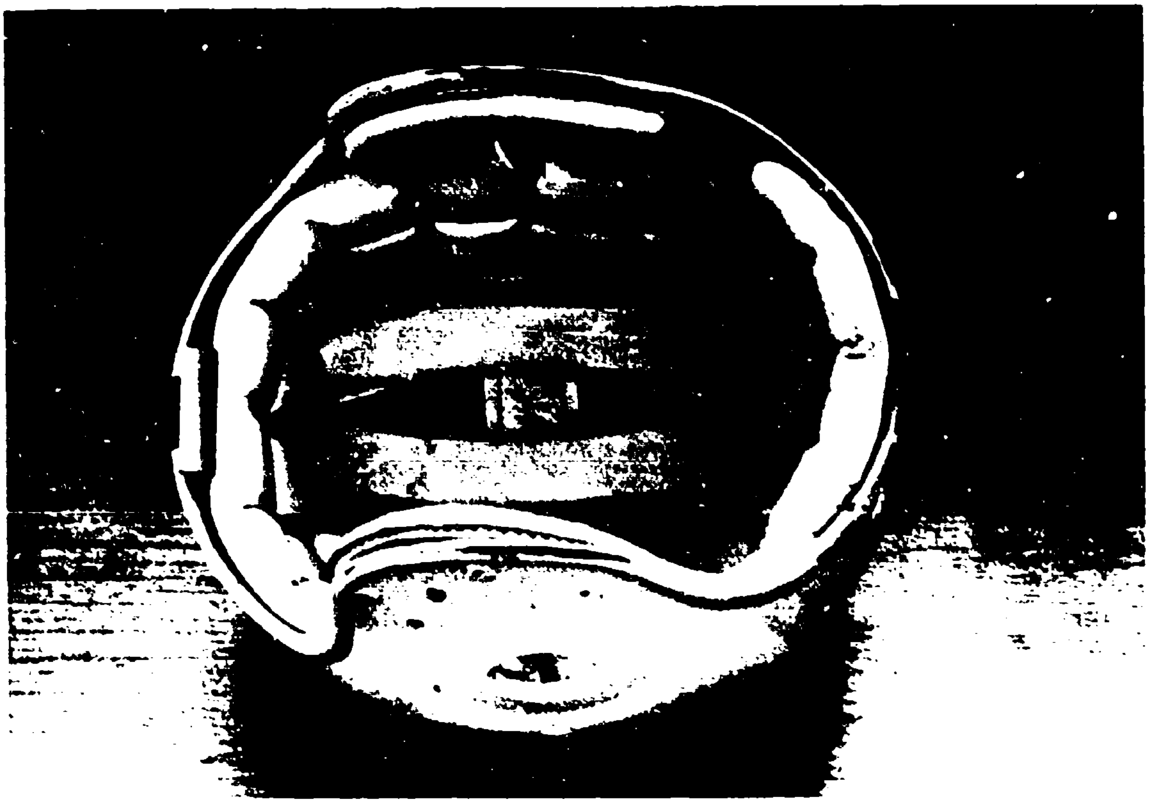

Figure 4. Helmet Four

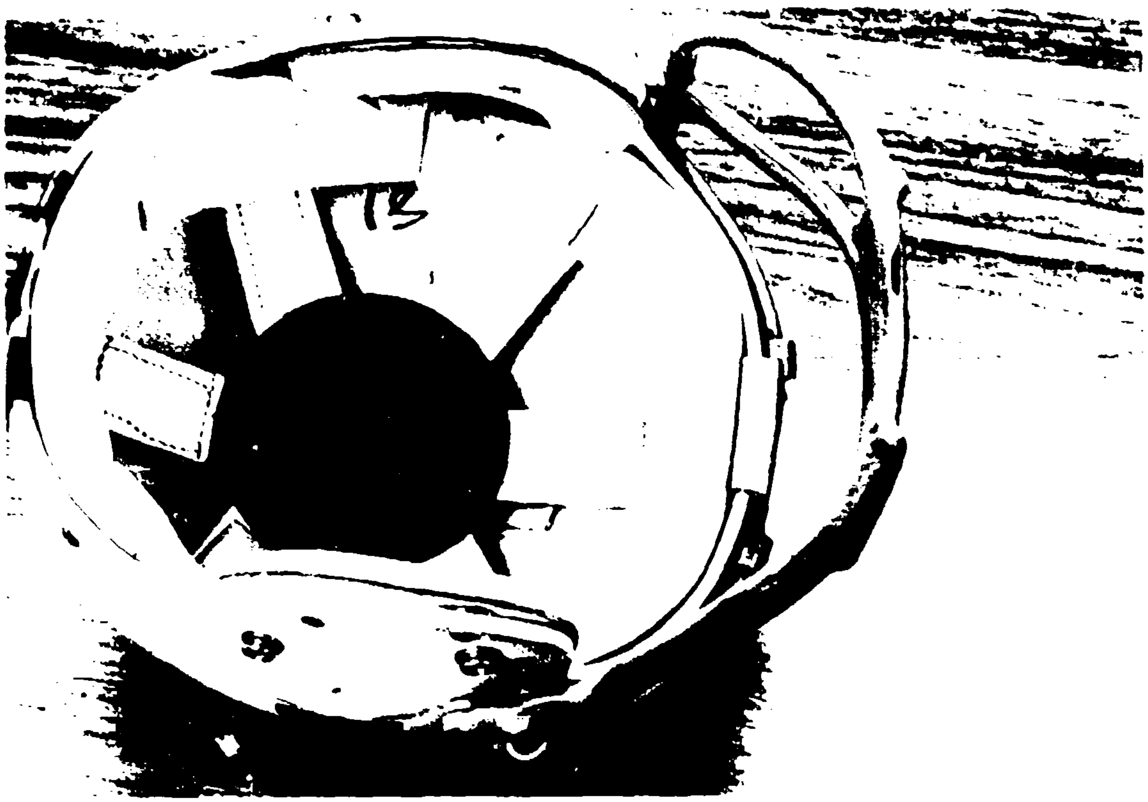

Figure 5. Helmet Five

Dependent Variables. Dependent variables recorded included ambient head temperature (helmet temperature) recorded from thermisters inserted 2.5 centimeters into the right anterior and left posterior quadrent of each helmet, rectal temperature recorded from a rectal probe inserted 15.5 centimeters, and heart rate recorded from EKG electrodes.

Treatment of Data. For this study a completely randomized factorial design with two replications was utilized. An analysis of variance using the F-test was selected to test the null hypotheses which were set at the .05 level of confidence. Duncan's multiple range test was performed on the means of the treatment groups to determine significant differences.

RESULTS

The mean results and F-ratios for the variables examined in this study are presented in Table 1 and Figures 6 and 7.

Ambient Head Temperature (Helmet Temperature). Analysis of data indicated that significant differences in helmet temperature existed among helmets (F=5.28) under all work levels and environmental conditions examined. Application of the Duncan test for evaluating mean differences identified helmet three as being significantly hotter than helmets one and five. Further analysis revealed that helmet temperature was significantly affected by work level (F=4.81). Inspection of Figure 6, mean temperatures among the five helmets for each

TABLE 1. F-Ratios for Independent Variables

Variable	F-Ratios		
	Helmet Temp.	Rectal Temp.	Heart Rate
Replication	.63	.01	.86
Helmet (a)	5.28[a]	1.90	.15
Environmental Condition (B)	477.72[a]	15.33[a]	4.5[illegible][a]
Work Level (C)	4.81[a]	.21	103.2[illegible][a]
AxB	1.99[a]	1.04	1.49
AxC	.15	.04	.14
BxC	.48	.11	.05
AxBxC	.15	.04	.14

[a]Significant at .05 level or better

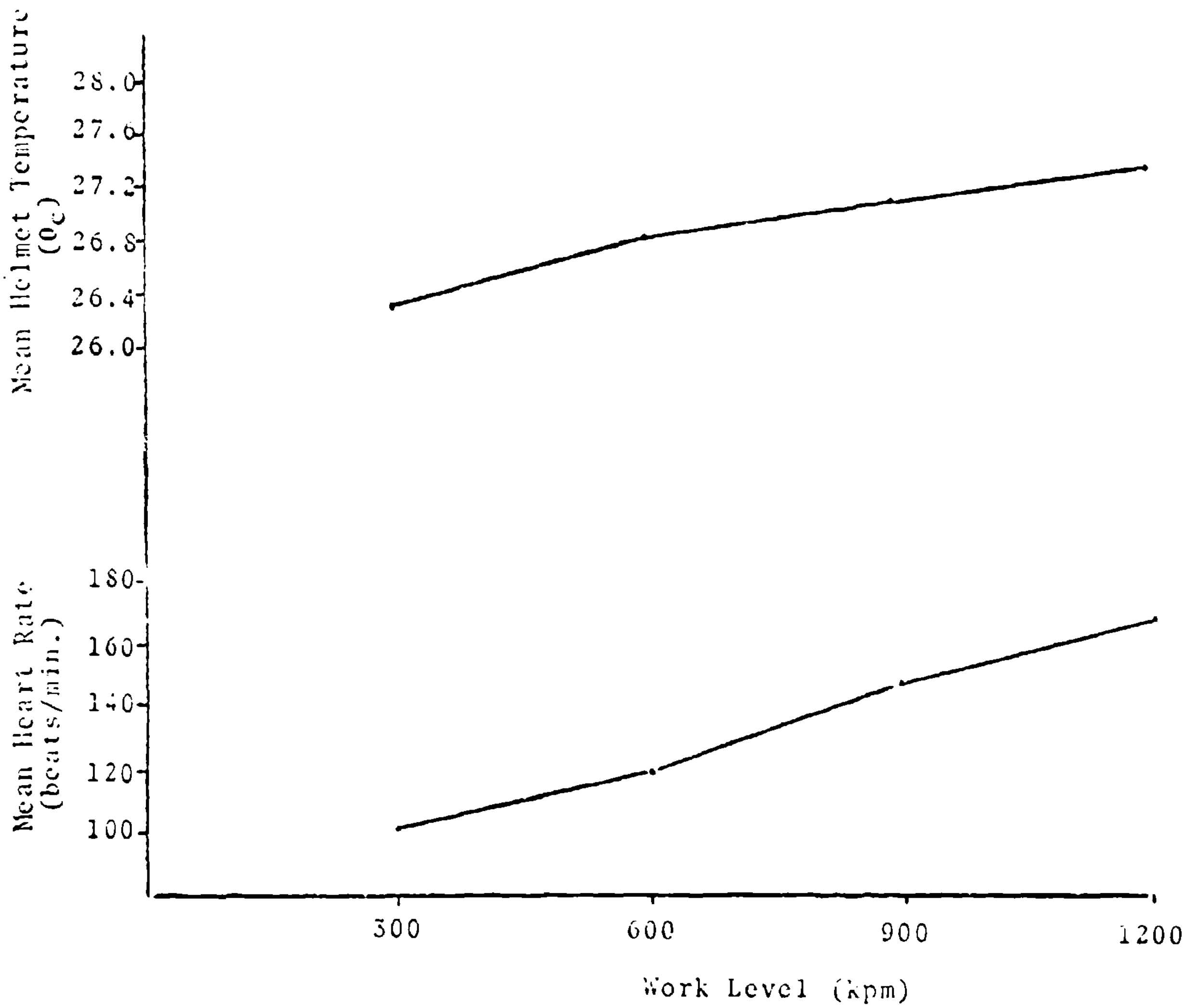

Figure 6. Mean helmet temperature and heart rate as a function of work level.

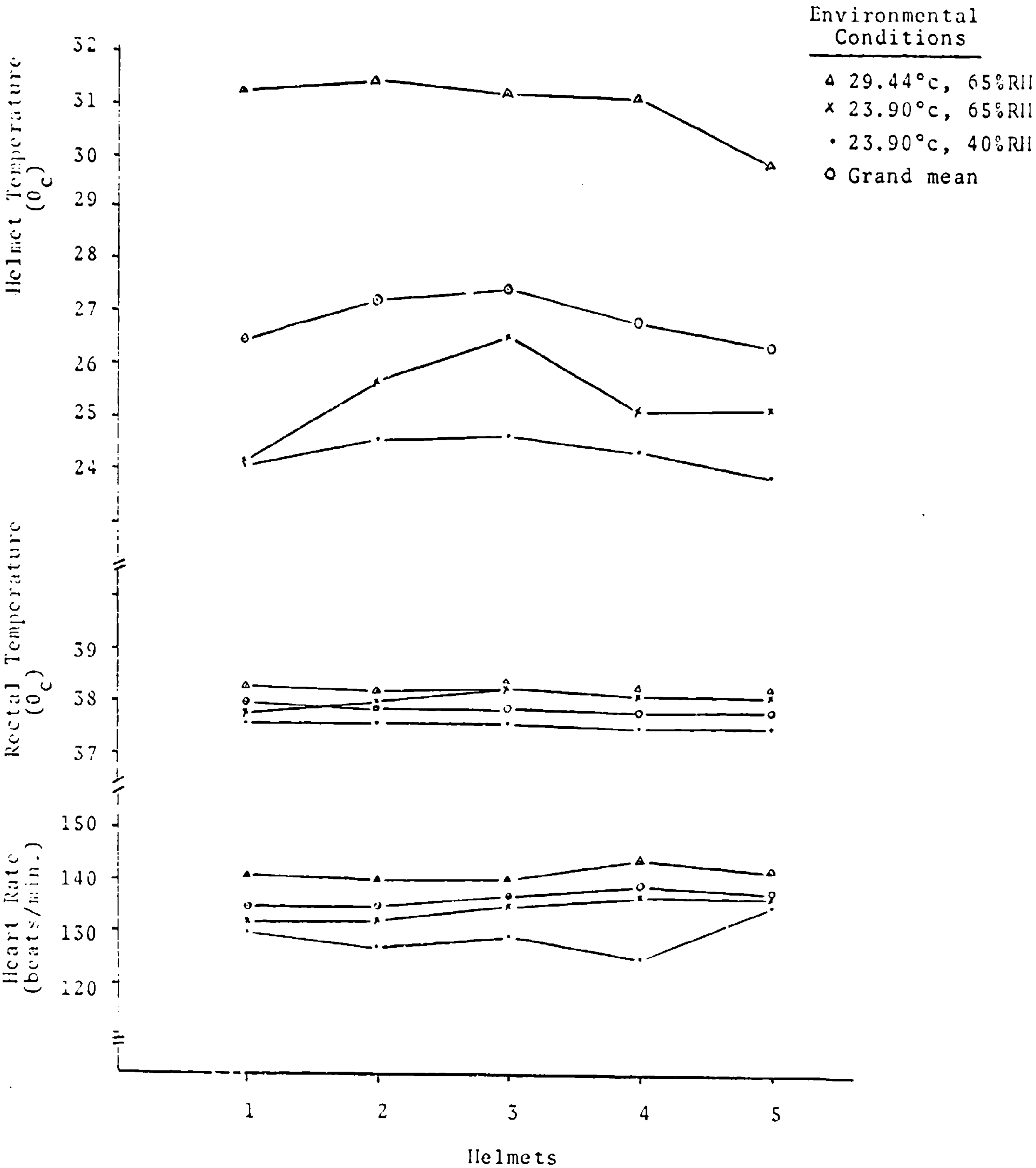

Figure 7. Mean helmet temperature, rectal temperature, and heart rate as a function of helmet design and environmental condition.

of the four work levels, indicates that helmet temperature increased linearly with successive increments in physical work. Difference between temperatures recorded for individual helmets at each work level were not significant as reflected by the non-significant (F=.15) helmet X work level interaction.

In addition to the relationships between helmet temperature and work level, significant Fs were also observed for environmental condition (F=477.72) and helmet X environmental condition interaction (F=1.99). The relationship between helmet temperature and the three levels of h t stress are presented in the upper portion of Figure 7. Inspection of this Figure indicates that the increases in temperature recorded for each helmet were parallel to the increases in environmental stress. Application of the Duncan test revealed that for all environmental conditions examined, helmets one and five were significantly cooler than helmets two, three, and four.

Rectal Temperature. Analysis of core temperature responses to exercise indicated that the only variable to significantly affect rectal temperature was environmental condition. The mean temperatures for the three conditions were 37.10, 38.05, and 38.27 degrees C, respectfully. The differences of .95C between condition one and two was significant beyond the .05 level of confidence. Differences between condition two and three were not significant.

Heart Rate. Mean heart rates recorded for subjects wearing the five helmets under the three levels of heat stress examined are presented in the lowe rtion of Figure 7. As anticipated (1, 3, 7), heart rate was not significantly affected by helmet design (F=.15), but was recorded as an index of cardiac stress as a precautionary measure. Although not related to helmets, the cardiac responses observed in this study were significantly affected by work load (F=103.27) and environmental stress (F=4.57). Application of the Duncan test to the heart rate - work level data showed that significant increments in heart rate occurred with successive increments in work load (Figure 6). A significant increment in pulse rate was also observed between environmental condition one and two. No significant difference was observed between conditions two and three.

DISCUSSION

The findings of this study indicate that helmets had an effect on the temperature of the air trapped beneath them. Since the primary difference between the helmets examined was in the design and texture of the internal suspension (padding) one may conclude that padding, rather than the helmets was the significant variable. It appears that padding has a detrimental effect on the circulation of air between the head and the helmet and consequently plays an important role in providing adequate ventilation for temperature regulation of the head. This is evident in Figure 7 which shows that the temperature recorded under each helmet exceeded the simulated environmental temperature by approximately 2 to 3 degrees. The magnitude of the difference between helmet temperature and chamber temperature varied from helmet to helmet with a mean difference of less than 2 degrees between the hottest and coolest helmet. Differences of this magnitude, while significant, may not be meaningful since removal of the helmet will facilitate heat dissipation and negate the differences observed between helmets.

On the basis of the information obtained in this study, the investigators suggest that as an aid in the dissipation of body heat, football players should be encouraged to remove helmets during time-outs and rest breaks. This procedure becomes more important as physical and environmental stresses increase. According to Fox, et al. (8), circulatory and thermal responses to exercise in full uniform under environmental conditions similar to those used in this study exceed those observed for subjects dressed in gym clothing. In addition to the increased heat production caused by its weight, the size and texture of the uniform may also significantly reduce the evaporative surface area of the body and decrease the effectiveness of the evaporative heat loss mechanism. As players continue to utilize more accessory protective equipment such as elbow, forearm and hand pads, this evaporative surface area is further reduced. The helmet is the only piece of protective equipment that can be removed and replaced quickly in order to facilitate heat dissipation. Removal of the helmet, when accompanied by the application of a cooling mechanism, ice pack, has been shown to be an effective means of facilitating heat loss in subjects dressed in gym clothing (10). The need exists to validate this procedure for subjects in full football uniform.

CONCLUSION

Since the differences between the heat retention properties of the helmets examined were marginal, the primary concern when purchasing helmets should be protection.

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APPENDIX A

Description of Helmets in Figures 1-5

Helmet One (Figure 1). Web suspension system with web bands over crown and peripheral web band.

Helmet Two (Figure 2). Multichamber inflatable suspension system with form fitting air pockets and fluid cells.

Helmet Three (Figure 3). Hammock suspension system with foam over crown bands and peripheral foam band. Foam covered with leather.

Helmet Four (Figure 4). Same as abcve except foam covered by vinyl.

Helmet Five (Figure 5). Web/foam suspension system with foam over web crown bands and peripheral foam band. Foam covered with vinyl.