MODEL AKTIVITAS PRAKTIKUM LAPANGAN BERBASIS ERGONOMI (APeLErg) MEMPERBAIKI RESPON FISIOLOGIS TUBUH, MENURUNKAN KELELAHAN, DAN MENINGKATKAN KINERJA, DIBANDINGKAN DENGAN MODEL LAMA (APeL), PADA MAHASISWA FMIPA UNIMA

Rolles Palilingan [1]✉, Adnyana Manuaba[2] , Nyoman Adiputra[2], Alex Pangkahila[2]
[1] School for Graduate Study, Udayana University
[2] Faculty of Medicine, Udayana University

E-mail: rollespalilingan@yahoo.com

ABSTRAK

Aktivitas praktikum lapangan merupakan kegiatan yang dilakukan sebagai implementasi kurikulum akademik di Jurusan Fisika FMIPA UNIMA. Sebagai implementasi kurikulum tersebut telah dibuat model aktivitas praktikum lapangan (model APeL) dan telah digunakan sejak tahun 2001. Namun model APeL ternyata menimbulkan risiko yang merugikan bagi mahasiswa dilihat dari respon fisiologis dan kelelahan sehingga mahasiswa belum dapat mencapai kinerja yang diharapkan. Untuk itu telah diupayakan dengan penerapan pendekatan ergonomi total (PET) suatu model baru yaitu model APeLErg. Untuk menguji keandalan model APeLErg dibandingkan dengan model APeL, telah dilakukan penelitian dengan hipotesis: model APeLErg, dibandingkan dengan model APeL; memperbaiki respon fisiologis tubuh; menurunkan kelelahan; dan meningkatkan kinerja mahasiswa di daerah dataran rendah/panas dan di daerah dataran tinggi/dingin. Penelitian ini dilakukan dalam dua tahap dengan menggunakan rancangan sama subjek. Penelitian pada tahap pertama dilakukan di daerah panas dengan menggunakan 15 orang subjek sedangkan penelitian tahap kedua di daerah dingin menggunakan 18 orang subjek. Hasil penelitian tahap I dan tahap II menunjukkan bahwa aktivitas dengan model APeLErg dapat: memperbaiki respon fisiologis mahasiswa secara signifikan ($p<0,05$); menurunkan rata-rata skor kelelahan umum secara signifikan ($p<0,05$); meningkatkan kecepatan, kekonstanan dan ketelitian mahasiswa secara signifikan ($p<0,05$); dan meningkatkan kinerja mahasiswa secara signifikan ($p<0,05$). Dari hasil penelitian ini dapat disimpulkan bahwa model APeLErg dapat: memperbaiki respon fisiologis mahasiswa; menurunkan tingkat kelelahan mahasiswa; dan meningkatkan kinerja mahasiswa dalam melakukan aktivitas praktikum lapangan.

Kata Kunci: Pendekatan Ergonomi Total, Model APeLErg, Respon Fisiologis, Kelelahan, Kinerja.

1. Pendahuluan

Dalam kegiatan akademik Jurusan Fisika FMIPA UNIMA, aktivitas praktikum lapangan merupakan kegiatan yang harus dan rutin dilakukan dalam Proses Belajar Mengajar (PBM), sebagai implementasi kurikulum baru tahun 2003 yang terakhir direvisi pada tahun 2005, kurikulum berbasis kompetensi. Agar aktivitas praktikum yang dilakukan terarah, maka pada periode tahun 2001 s/d 2004 telah dibuat suatu panduan praktikum, dimana menurut pendapat Gene Bellinger (2004), Kuhne (2005), BP-PLSP

(2006), VSSD (2007), dan Sudrajat (2007) panduan semacam itu termasuk model. Dalam konteks penelitian ini model tersebut dinamakan model APeL.

Penelitian observasional dengan menggunakan model APeL yang dilakukan oleh Palilingan (2007) dan Palilingan dan Pungus (2007) menunjukkan bahwa aktivitas praktikum lapangan dengan model APeL ternyata menimbulkan risiko yang kurang menguntungkan bagi mahasiswa. Hal tersebut terlihat dari perubahan respon fisiologis tubuh dan kelelahan mahasiswa secara signifikan ($p<0,05$) setelah berada di arena praktikum dibandingkan dengan sebelum turun ke arena. Suhu oral dan denyut nadi berubah ke level yang kondisi hipertermia (suhu tubuh>38^oC) dan keadaan inefisiensi sistem sirkulasi (denyut nadi>90 denyut/menit). Skor kelelahan umum juga menunjukkan peningkatan yang signifikan ($p<0,05$) setelah berada di arena praktikum. Dengan demikian dapat dikatakan bahwa model aktivitas praktikum lapangan yang sudah ada atau model APeL belum dapat dikatakan ergonomis. Oleh karena itu dapat pula dimengerti mengapa kinerja mahasiswa masih jauh dari target ideal (100%), yaitu hanya mencapai 65,89%.

Permasalahan yang berhubungan dengan respon fisiologis, kelelahan dan kinerja mahasiswa dalam melakukan aktivitas praktikum lapangan di daerah dataran rendah/panas maupun di daerah dataran tinggi/dingin hanya dapat dipecahkan dengan baik apabila menggunakan pendekatan yang bersifat komprehensif, dan pendekatan yang memenuhi sifat tersebut adalah pendekatan ergonomi total yang memadukan pendekatan SHIP (sistemis, holistis, interdisipliner, partisipasi) dan kajian TTG (teknologi tepat guna) Manuaba (2004b; 2005a; 2005b). Dengan penerapan pendekatan ergonomi total pada sistem kerja aktivitas praktikum lapangan dengan menggunakan kajian delapan aspek ergonomi (Manuaba, 1992; Manuaba, 2003; Palilingan, 2006) sebagai bagian dari proses penerapan pendekatan ergonomi total, yang berfungsi sebagai *tool*, maka faktor-faktor penyebab permasalahan dapat diungkap secara komprehensif dan ternyata bahwa dalam pelaksanaan praktikum lapangan dengan model aktivitas yang sudah ada, delapan aspek ergonomi belum mendapat perhatian yang semestinya.

Mengingat risiko kurang baik yang dialami mahasiswa dalam aktivitas praktikum lapangan dengan menggunakan model APeL maka perlu disusun suatu model baru yang memasukkan faktor-faktor yang relevan untuk intervensi sebagaimana yang sudah disebutkan sebagai elemen-elemen dari model dengan menggunakan pendekatan ergonomi total. Dengan model baru tersebut, yang selanjutnya disebut model aktivitas praktikum lapangan berbasis ergonomi atau model APeLErg, maka diprediksi bahwa mahasiswa dapat melakukan aktivitas dengan respon fisiologis yang lebih baik dan tidak mengalami kelelahan yang berarti dan dapat mencapai kinerja yang diharapkan.

Hipotesis yang diuji dalam penelitian ini adalah: model APeLErg, dibandingkan dengan model APeL; memperbaiki respon fisiologis tubuh; menurunkan kelelahan; dan meningkatkan kinerja mahasiswa di daerah dataran rendah/panas dan di daerah dataran tinggi/dingin.

2. Bahan dan Diskusi

Penelitian ini dilakukan di dua lokasi yaitu Manado yang mewakili daerah dataran rendah/panas (elevasi 0-200 m), dan Rurukan yang mewakili dataran tinggi/dingin (elevasi > 1000 m) (PEMDA Kab. Minahasa, 2004). Penelitian ini adalah penelitian eksperimental sungguhan (*true experimental*) dengan menggunakan rancangan sama subjek (*treatment by subject design*) (Colton, 1985; Dimitrov and Rumrill, 2005; Hudock, 2005). Populasi target adalah seluruh mahasiswa Jurusan Kimia FMIPA Universitas Negeri Manado yang berjumlah 169 orang dan populasi terjangkau adalah seluruh mahasiswa semester II Jurusan Kimia FMIPA UNIMA yang berjumlah 39 orang. Besar sampel ditentukan berdasarkan informasi penelitian pendahuluan pada aktivitas praktikum lapangan (Palilingan dan Pungus, 2007) dengan menggunakan formula Colton (1985) dengan α = 0,05; β = 0,05. Sampel yang digunakan adalah 15 orang di daerah dataran rendah/panas dan 18 orang di daerah dataran tinggi/dingin. Pengukuran variabel tergantung baik pada aktivitas model APeL dan aktivitas model APeLErg dilakukan sebelum dan selama berada di arena praktikum, yaitu: I (sebelum), II, menit 40-50; III, menit 90-100; IV, menit 140-150; V(akhir), menit 190-220. Aktivitas praktikum dilakukan selama ± 4 jam.

Pada aktivitas dengan model APeL, di daerah dataran rendah/panas, ditemukan bahwa rata-rata suhu oral (dalam ^oC) pada pengukuran I s/d V adalah: 36,827±0,308 (awal); 37,380±0,234 (II); 37,867±0,633 (III); 37,973±0,768 (IV); dan 38,513±1,468^oC (akhir), sedangkan pada aktivitas dengan model APeLErg adalah: 36,813±0,253 (awal); 37,073±0,284 (II); 37,147±0,380 (III); 37,227±0,437 (IV); dan 37,093±0,301^oC (akhir). Menurut Ganong (1983) rata-rata suhu oral biasanya lebih rendah 0,5 ^oC dibanding rata-rata suhu inti tubuh (suhu rektal). Suhu inti tubuh normal menurut Wenger (2001) dan Derchak,Ostertag, and Coyle (2004) berkisar 36,5 s/d 37,5 ^oC; dan menurut Gleeson (2001) berkisar 36 s/d 38 ^oC. Berarti bahwa pada aktivitas dengan model APeL dan model APeLErg rata-rata suhu inti tubuh mahasiswa sebelum turun ke arena praktikum masih berada pada kisaran normal. Setelah berada di arena, pada aktivitas dengan model APeL suhu inti tubuh naik di atas normal atau mengalami kondisi hipertermia, sedangkan pada aktivitas dengan model APeLErg tetap normal. Dalam hal ini, pada aktivitas dengan model APeL, panas yang diproduksi melalui proses metabolisme terhalang untuk dilepaskan ke luar tubuh, padahal menurut Presedent's Council on Physical Fitness and Sports (2007) dari energi yang diproduksi tubuh hanya 25% yang digunakan untuk melakukan kerja dan 75% dikonversi menjadi panas, sedangkan menurut Lim, Byrne, and Lee (2008) selama aktivitas fisik lebih dari 80% panas dalam tubuh harus dilepaskan ke lingkungan. Bila dilihat hubungan dengan beban kerja, menurut Christensen (dalam Nurmianto, 2004), maka beban kerja dalam aktivitas dengan model APeL termasuk beban kerja sedang sampai sangat berat dengan suhu inti tubuh 37,5^{o}C s/d lebih dari 39^{o}C dan pada aktivitas dengan model APeLErg termasuk beban kerja sedang dengan suhu inti tubuh 38 s/d 38,5.

Pada aktivitas dengan model APeL ditemukan bahwa rata-rata denyut nadi (dalam denyut/menit) pada pengukuran I s/d V adalah: 85,067±7,186 (awal); 110,600±15,301 (II); 106,600±11,438 (III); 103,533±12,822 (IV); dan 104,000±14,182 (akhir), sedangkan pada aktivitas dengan model APeLErg adalah: 82,200±5,809 (awal); 88,000±6,814 (II); 91,733±10,229 (III); 90,067±11,411 (IV); dan 89,933±11,689 denyut/menit (akhir). Bila dilihat hubungan dengan beban kerja, menurut Christensen (dalam Nurmianto, 2004), maka beban kerja aktivitas dengan model APeL tergolong beban kerja sedang yang berkisar 100–125 denyut/menit. Pada aktivitas dengan model APeLErg tergolong beban kerja ringan yang berkisar 75–100 denyut/menit.

Pada aktivitas dengan model APeL ditemukan bahwa rata-rata skor kelelahan umum akhir dengan *30 items rating of scale* adalah 83,933±15,234 sedangkan pada aktivitas dengan model APeLErg menurun secara signifikan ($p<0,05$) menjadi 69,067±13,041 atau turun 17,713 %. Kenyataan ini diperkuat oleh adanya peningkatan tingkat kecepatan, kekonstanan dan ketelitian sebesar: tingkat kecepatan lebih tinggi 13,481%; tingkat kekonstanan lebih tinggi 37,644%, dan tingkat ketelitian lebih tinggi 32,779%.

Pada aktivitas dengan model APeL ditemukan bahwa rata-rata kinerja mahasiswa secara keseluruhan dengan empat unit praktikum adalah 30,761±1,412% sedangkan pada aktivitas dengan model APeLErg meningkat secara signifikan ($p<0,05$) menjadi 54,341±10,949% atau meningkat 76,659%.

Pada aktivitas dengan model APeL, di daerah dataran tinggi/dingin, ditemukan bahwa rata-rata suhu oral (dalam ^{o}C) pada pengukuran I s/d V adalah: 36,233±0,397 (awal); 36,506±0,404 (II); 36,650±0,370 (III); 36,550±0,391 (IV); dan 36,639±0,311^{o}C (akhir), sedangkan pada aktivitas dengan model APeLErg adalah: 36,144±0,396 (awal); 36,578±0,273 (II); 36,600±0,272 (III); 36,456±0,301 (IV); dan 36,622±0,286^{o}C (akhir).

Pada aktivitas dengan model APeL ditemukan bahwa rata-rata denyut nadi (dalam denyut/menit) pada pengukuran I s/d V adalah: 79,222±8,207 (awal; 101,556±10,837 (II); 98,889±11,926 (III); 97,889±11,631 (IV); dan 96,667±10,738 (akhir), sedangkan pada aktivitas dengan model APeLErg adalah: 77,222±4,181 (awal); 88,778±10,356 (II); 86,722±13,982 (III); 82,611±13,320 (IV); dan 89,389±11,392 denyut/menit (akhir).

Di daerah dataran tinggi/dingin, rata-rata skor kelelahan umum awal berbeda secara signifikan ($p<0,05$). Karena itu perbedaan skor kelelahan dilihat dari selisih skor akhir dan awal. Hasil uji beda rata-rata selisih skor kelelahan menunjukkan bahwa rata-rata selisih skor kelelahan mahasiswa pada aktivitas dengan model APeL berbeda secara signifikan dengan rata-rata selisih skor kelelahan pada aktivitas dengan model APeLErg yang ditunjukkan dengan nilai $p<0,05$ dan terjadi penurunan 34,008%. Kenyataan ini diperkuat oleh adanya peningkatan tingkat kecepatan, kekonstanan dan ketelitian sebesar: tingkat kecepatan lebih tinggi 14,598%; tingkat kekonstanan lebih tinggi 37,756%, dan tingkat ketelitian lebih tinggi 24,053%.

Pada aktivitas dengan model APeL ditemukan bahwa rata-rata kinerja mahasiswa secara keseluruhan dengan empat unit praktikum adalah 41,572±1,314 % sedangkan pada pada aktivitas dengan model APeLErg meningkat secara signifikan ($p<0,05$) menjadi 67,109 ± 1,489% atau meningkat 61,428%.

Berdasarkan hasil-hasil mengenai suhu inti tubuh (suhu oral), denyut nadi, kelelahan dan kinerja mahasiswa di daerah dataran rendah/panas dan di daerah dataran tinggi/dingin maka dapat dikemukakan hal-hal berikut ini. Model APeLErg berhasil, terutama di daerah dataran rendah/panas, mengubah kondisi hipertermia yang di alami mahasiswa sebagai penyebab utama kelelahan fisik dan mental (Nielsen et.al., 1993; Gonzalez et.al. 1999; Gleeson, 2001; Brake and Bates, 2001; Brake and Bates, 2002; Rodahl, 2003; Tenford, 2003; Brearley and Finn, 2003; Stephan et.al., 2003; Cheung and Sleivert, 2004; Horikoshi et.al., 2004; dan Presedent’s Council on Physical Fitness and Sports, 2007) selama aktivitas, menjadi kondisi normal. Model APeLErg berhasil meningkatkan efisiensi sistem sirkulasi yang ditandai dengan penurunan denyut nadi secara signifikan (Fox, Bowers and Foss, 1988; Derchak, Ostertag, and Coyle, 2004; Blazejczyk and Blazejczyk, 2007). Model APeLErg berhasil meredam pengaruh buruk keterpaparan langsung pada sinar matahari dan sikap kerja yang repetitif dan tidak fisiologis (Rodahl, 2003; Horikoshi, 2004). Model APeLErg berhasil menurunkan beban kerja sedang sampai sangat berat menjadi sedang dilihat dari suhu inti tubuh, dan beban kerja sedang menjadi ringan dilihat dari denyut nadi. Kenyataan perbaikan respon fisiologis dan penurunan tingkat kelelahan merupakan faktor pendukung utama terhadap peningkatan kinerja mahasiswa (Gonzalez, 1999; Schafer, 1999; Brearley and Finn, 2003; Tenford, 2003; Rodahl, 2003; Presedent's Council on Physical Fitness and Sports, 2007).

Temuan baru dalam penelitian ini adalah model aktivitas praktikum lapangan berbasis ergonomi yang disebut model APeLErg, termasuk di dalamnya semua perangkat model sebagai suatu kesatuan yang tidak terpisahkan. Wujud nyata dari model APeLErg adalah suatu paket pembelajaran yang berbentuk modul yang terdiri dari empat bagian besar, yaitu: (1) deskripsi syarat penggunaan model; (2) panduan umum; (3) panduan khusus; dan (4) Evaluasi kinerja.

3. Simpulan

Berdasarkan hasil-hasil yang diperoleh dalam penelitian ini maka dapat disimpulkan bahwa model aktivitas praktikum lapangan berbasis ergonomi (model APeLErg), dibandingkan dengan model APeL, dapat: memperbaiki respon fisiologis tubuh mahasiswa dilihat dari parameter suhu oral dan denyut nadi kerja; menurunkan kelelahan mahasiswa dilihat dari parameter skor kelelahan umum serta skor kecepatan, kekonstanan dan ketelitian; dan meningkatkan kinerja mahasiswa, di dalam melakukan aktivitas praktikum lapangan di daerah dataran rendah/panas dan di daerah dataran tinggi/dingin.

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MODEL ACTIVITY OF ERGONOMICS - BASED FIELD WORK (APeLErg), COMPARED WITH THE CONVENTIONAL ONE (APel), IMPROVES PHYSIOLOGICAL RESPONSES, DECREASES FATIGUE, AND INCREASES PERFORMANCE OF THE STUDENTS OF FMIPA UNIMA

Rolles Palilingan, Adnyana Manuaba, Nyoman Adiputra, Alex Pangkahila
Postgraduate Program, Medical Science
Udayana University

E-mail: rollespalilingan@yahoo.com

ABSCTACT

Field work activity is conducted as the implementation of the academic curriculum of the Physics Department of FMIPA UNIMA. To implement the curriculum, a model of field work (APeL model) has been made and applied since 2001. However, the APeL model turned out to cause unfavorable risks to the students based on physiological responses and fatigue so that they could not attain the intended performance yet. Therefore, by applying total ergonomics approach (TEA), a new model namely APeLErg has been made. In order to test the capability of the model, compared with APeL model, a research has been conducted with the hypothesis: the APeLErg model, compared with the APeL model, improves physiological responses; decreases fatigue; and increases performance of the students both in low land/hot area and in high land/cool area. This research was done in two steps by employing the design of treatment by subject. The research on the first step was done in hot area (low land) by involving 15 subjects while in the second step it was done in cool area (heigh land) by involving 18 subjects. The results of the research both in step I and step II showed that the activity of APeLErg model could significantly: (1) improve physiological responses of the students ($p<0.05$); (2) decrease the mean of general fatigue score of the students ($p<0.05$); (3) increase the speed, constancy, and accuracy of the students ($p<0.05$); and (4) increase the performance of the students ($p<0.05$). Based on the research, it can be concluded that the APeLErg model can: improve the physiological responses of the students; decrease the level of fatigue of the students; and increase the performance of the students in doing the field work activity.

Key Words: Total Ergonomics Approach, APeLErg Model, Physiological responses, fatigue, performance.

3. Introduction

In academic activities of the Physics Departement of FMIPA UNIMA, field work is a must and routine activity which is performed in learning and teaching process, as the implementation of 2003's new academic curriculum which was revised in 2005, that is competency based curriculum (Jurusan Fisika, 2003). To make the activity directed, from 2001 to 2004 a guidance of field work was created which, according to Gene Bellinger (2004), Kuhne (2005), BP-PLSP (2006), VSSD (2007), and Sudrajat (2007), was supposed to be a model. In the context of this research such a model is called APeL model.

Observational research employing the APeL model conducted by Palilingan (2007), Palilingan, and Pungus (2007) showed that the activity with the APeL model turned out to cause unfavorable risks to the students. The risks were noticeable from the significant changes in physiological responses and fatigue level ($p<0, 05$) after being in the field work arena compared with before being in the arena. Oral temperature and heart rate changed to the hyperthermia level (temperature $>38^{o}$C) and inefficient condition of circulatory system (heart rate >90 beat/minute). Fatigue score of category of activity deflation (items 1-10), motivation deflation (items 11-20), general physical fatigue (items 21-30), and the combination of the three categories also showed significant increase while existing in the field work arena. Thus, it can be stated that the APeL model is not yet ergonomic. Therefore, it can be understood why the performance of the students was still far from the ideal target, that is, they just attained 65, 89%.

A set of problems related to physiological responses, fatigue, and performance of the students in implementing the field work activity both in low land/hot area and in high land/cool area could only be well solved by applying comprehensive approach. Such an approach is totally ergonomic approach (TEA) integrating SHIP approach (systemic, holistic, interdisciplinary, participatory) and appropriate technological assessment (ATA) (Manuaba, 2004b; 2005a; 2005b). By applying totally ergonomic approach in field work activity using the eight aspects of ergonomics (Manuaba, 1992; Manuaba, 2003; Palilingan, 2006) as a part of the application process of the totally ergonomic approach functioning as a tool, then the factors causing the set of problems can be significantly revealed and it turns out that no proportional attention has been paid to the eight aspects of ergonomics.

Because of the unfavorable risks undergone by the students in using the APeL model in the field work activity, then it is necessary to arrange a new model which includes relevant factors for intervention as stated to be the elements of the model. By the new model, namely APeLErg model, it can be predicted that the students can perform the activity with good physiological responses and do not undergo fatigue symptom and can get the intended performance.The hypothesis to be tested in the research is: the APeLErg model, compared with the APeL model, improves the physiological responses; decreases the fatigue; and increases the performance of the students both in low land/hot area and in high land/cool area.

4. Material and Discussion

The research was conducted in two locations, that is, in Manado as low land/hot area (elevation 0–200 m above sea level) and in Rurukan as high land/cool area. (elevation > 1000 m above sea level) (PEMDA Kab. Minahasa, 2004). The research was truely experimental using treatment by subject design (Colton, 1985; Dimitrov and Rumrill, 2005; Hudock, 2005). The target population of the research was 169 students of the Chemistry Departement of FMIPA UNIMA and the reached population was 39 students of Semester II of the Chemistry Departement. The size of the samples was calculated based on the initial research information on field work activity (Palilingan and Pungus, 2007) using Colton formula (Colton, 1985) with α = 0, 05; β = 0, 05. The largest amount of n was 10, 76 and then 10% was added to the number of the samples resulting in 12 people. With multi-stage random sampling technique and with reference to the inclusion and dropout criteria, the last size of the samples was 15 people in low land/hot area and 18 people in high land/cool area. The measurements of the dependent variables both in the activity with APeL model and in the APeLErg model were done prior to and during being in the field work arena, those are: I (prior to); II, minutes 40-50; III, minutes 90-100; IV, minutes 140-150; and V (the last), minutes 190-220. The activity was performed for ±4 hours.

In the activity with the APeL model, in low land/hot area, it was revealed that the averages of oral temperature (in ^{o}C) in measurement I up to V were: 36,827±0,308 (initial); 37,380±0,234 (II); 37,867±0,633 (III); 37,973±0,768 (IV); and V, 38,513±1,468^{o}C (end of period), while in the activity with the APeLErg model they significantly decreased ($p<0,05$): 36,813±0,253 (initial); 37,073±0,284 (II); 37,147±0,380 (III); 37,227±0,437 (IV); and V (end of period), 37,093±0,301^{o}C. According to Ganong (1983) the average of oral temperature was normally 0,5oC lower than the average of body core temperature (rectal temperature). The normal core body temperature according to Wenger (2001) and Derchak, Ostertag, and Coyle (2004) varied from 36, 5 up to 37,5^{o}C; and according to Gleeson (2001)it varied from 36 to 38 ^{o}C. It meant that in the activity with the APeL model and with the APeLErg model, the body core temperatures of the students before being in the arena were normal. While the students were being in the arena, in the activity with the APeL model, the body core temperature increased above normal level or was being in hyperthermia condition, while in the activity with the APeLErg model it was constantly normal. In this case, the heat produced by metabolism process was obstructed to be released outward of the body, whereas according to Presedent's Council on Physical Fitness and Sports (2007) out of the energy produced by the body only 25% was used to perform work and 75% was conversed as heat, while according to Lim, Byrne, and Lee (2008) during physical activity more than 80% of the heat in the body must be released to the environment. In relation to workload, according to Christensen (in Nurmianto, 2004), the workload in the activity with the APeL model was included as moderate up to very high workload with 37,5^{o}C up to more than 39^{o}C body core temperature. The work load in the activity with the APeLErg model was included as moderate from 38 to 38, 5 body core temperature.

In the activity with the APeL model, it was revealed that the averages of heart rate of measurement I up to V (in beat/minute) were: 85,067±7,186 (initial); 110,600±15,301 (II); 106,600±11,438 (III); 103,533±12,822 (IV); and 104,000±14,182 beat/minute (end of period), while in the activity with the APeLErg model, the averages significantly decreased (p<0,05): 82,200±5,809 (initial); 88,000±6,814 (II); 91,733±10,229 (III); 90,067±11,411 (IV); and V, 89,933±11,689 beat/minute (end of period). In relation to workload, according to Christensen (in Nurmianto, 2004), the workload in the activity with the APeL model was included as moderate workload with from 100 to 125 beat/min body heart rate. The work load in the activity with the APeLErg model was included as low workload from 75 to 100 beat/min body heart rate.

In the activity with the APeL model it was uncovered that the average of fatigue score in the end of the activity (after finishing the activity) was 83.933±15.234, while in the activity with the APeLErg model it significantly decreased (p<0, 05) to 69,067±13.041 or decreased 17.713%. The fact was supported by: the level of speed which was 13.481% higher; the level of constancy which was 37.644% higher; the level of accuracy which was 32.779% higher than the activity with the APeL model.

In the activity of the APeL model it was uncovered that the average of performance of the students (unit-1 up to unit-4) was 30,761±1,412%, while in the activity with the APeLErg model it significantly increased (p<0, 05) to 54,341±10,949% or increased 76,659%.

In the activity with the APeL model, in high land/cool area, it was uncovered that the averages of oral temperature (in ^{o}C) in measurement I up to V were: 36,233±0,397 (initial); 36,506±0,404 (II); 36,650±0,370 (III); 36,550±0,391 (IV); and V (end of period), 36,639±0,311^{o}C, while in the activity with the APeLErg model they were: 36,144±0,396 initial); 36,578±0,273 (II); 36,600±0,272 (III); 36,456±0,301 (IV); and V (end of period), 36,622±0,286^{o}C.

In the activity with the APeL model, it was found out that the averages of heart rate of measurement I up to V (in beat/minute) were: 79,222±8,207 (initial); 101,556±10,837 (II); 98,889±11,926 (III); 97,889±11,631 (IV); and V (end of period), 96,667±10,738 beat/minute, while in the activity of the APeLErg model they significantly decreased ($p<0,05$) to: 77,222±4,181 (initial); 88,778±10,356 (II); 86,722±13,982 (III); 82,611±13,320 (IV); and V (end of period), 89,389±11,392 beat/minute.

In high land/cool area, the average of fatigue score before the activity was significantly different ($p<0, 05$). Therefore, the mean difference of fatigue score could be seen from the difference of the last from the initial score. The mean difference test of the last and initial score of fatigue showed that the average of the difference score of fatigue of the students in the activity with the APeL model and the APeLErg model were significantly different which was shown by the value of $p<0,05$ and the occurance of a decrease of 34,008%. The fact was supported by the increase in: the level of speed which was 14,598% higher; the level of constancy which was 37,756% higher; the level of accuracy which was 24,053% higher than the activity with the APeL model.

In the activity of the APeL model it was found out that the average of performance of the students (unit-1 up to unit-4) was 41,572±1,314%, while in the activity with the APeLErg model it significantly increased ($p<0,05$) to 67,109±1,489% or increased 61,428%.

Based on the results of the body core temperature (oral temperature), working heart rate, fatigue, and performance of the students both in low land/hot area and in high land/cool area, then the following thing can be stated: the APeLErg model is successful (especially in low land/hot area) in changing the hyperthermia condition undergone by the students as the principal cause of physical and mental fatigue (Nielsen et.al., 1993; Gonzalez et.al., 1999; Gleeson, 2001; Brake and Bates, 2001; Brake and Bates, 2002; Rodahl, 2003; Tenford, 2003; Brearley and Finn, 2003; Stephan et.al., 2003; Cheung and Sleivert, 2004; Horikoshi et.al., 2004; and Presedent's Council on Physical Fitness and Sports, 2007) into normal during performing the activity. The APeLErg model is successful in increasing the efficiency of circulatory system certified by the significant decrease in heart beat rate (Fox, Bowers and Foss, 1988; Derchak, Ostertag, and Coyle, 2004; Blazejczyk and Blazejczyk, 2007). The APeLErg model is successful in preventng the students from unfavorable risks due to direct exposure to solar radiation and work posture that is repetitive and is not physiological (Rodahl, 2003: Horikoshi, 2004). The APeLErg model is successful in decreasing moderate up to very high workload to moderate workload evaluated from the body core temperature, and moderate workload to low workload evaluated from the working heart rate. The fact that improvement in physiological responses and decrease in fatigue are the principal factors which support the performance of the students (Gonzalez et.al., 1999; Schafer, 1999; Brearley and Finn, 2003; Tenford, 2003; Rodahl, 2003; Presedent's Council on Physical Fitness and Sports, 2007).

6. Conclusion

Based on the results and discussion of the research, it can be concluded that the APeLErg model, compared with the APeL model, can: improve the physiological responses of the students evaluated from the parameters of oral temperature and working heart rate; decrease fatigue of the students evaluated from the parameters of general fatigue score, speed, constancy, and accuracy score; and increase the performance of the students in performing the field work activity both in low land/hot area and in high land/cool area.

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