PENGARUH PERUBAHAN LETAK TITIK BERAT DAN TITIK TUMPU TUBUH KERJA BUBUT POSISI BERDIRI TERHADAP KELELAHAN OTOT BIOMEKANIK

(PENELITIAN EKSPERIMENTAL ERGONOMIS MENGGUNAKAN PENDEKATAN METABOLISME ENERGI ANAEROBIK)

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RINGKASAN

Penelitian ini mempelajari pengaruh perubahan letak titik berat (TB) dan titik tumpu (TT) tubuh kerja bubut posisi berdiri terhadap kelelahan otot biomekanik. Permasalahan tersebut dilatarbelakangi bahwa sampai saat ini tenaga kerja posisi berdiri masih banyak mengalami kelelahan (Yassierli et.al, 2000; Gempur, 2001), *back pain* (Duquette, 1997), dan *lumbar lordosis* (Lord et.al, 1997). Pekerjaan bubut manual merupakan jenis pekerjaan yang sampai saat ini dilakukan dengan kerja posisi berdiri tegak (TG). Perubahan letak TB dan TT tubuh yang dimaksud adalah letak TB dan TT pada kerja bubut posisi berdiri tegak (TG) diubah menjadi letak TB dan TT pada kerja bubut posisi berdiri setengah duduk tanpa sandaran (SDTS) maupun pada kerja bubut posisi berdiri pakai sandaran (SDPS). Kelelahan otot biomekanik merupakan kelelahan otot skelet yang diukur berdasarkan metabolisme energi anaerobik (MEA) yakni diukur berdasarkan konsentrasi asam laktat dan glukosa.

Redesain kerja bubut posisi berdiri dengan cara merubah letak TB dan TT tubuh tersebut, diharapkan mendapatkan posisi berdiri yang lebih ergonomis. Dengan demikian, dapat menghilangkan atau mengurangi kelelahan otot biomekanik berdasarkan konsep MEA, yang pada akhirnya diharapkan dapat meningkatkan produktivitas kerja tenaga kerja bubut.

Metode penelitian ini dirancang menggunakan jenis penelitian eksperimental secara *pre-post control group design*, yakni mengukur kelelahan otot biomekanik sebelum dan sesudah kerja antara kelompok kontrol dengan tiga kelompok perlakuan. Kelompok kontrol (K) adalah kelompok kerja bubut yang tidak melakukan aktivitas kerja. Tiga kelompok perlakuan antara lain: kelompok kerja bubut dengan letak TB dan TT tubuh posisi berdiri TG, SDTS, dan SDPS. Populasi penelitian ini adalah peserta latihan calon tenaga kerja bubut manual di Balai Latihan Kerja Industri dan Pengembangan (BLKIP) Surabaya, sejumlah 60 tenaga kerja (naker). Pengambilan sampel penelitian dilakukan secara kriteria dan random. Secara kriteria, dari 60 naker yang memenuhi kriteria sebesar 58 naker. Kemudian, dari 58 naker diambil secara random 40 naker peserta dalam penelitian. Selanjutnya, dari 40 naker dibagi dalam 4 kelompok, masing-masing 10 naker. Karena ada 4 naker pada kelompok K mengundurkan diri, maka besar sampel kolompok K menjadi 6 naker.

Hasil penelitian menunjukkan bahwa MEA sebelum kerja antar kelompok adalah sama ($p' > 0,05$). Namun, sesudah kerja MEA antar kelompok terjadi perbedaan ($p' < 0,05$). Terdapat perbedaan respons MEA antar kelompok ($p' < 0,05$). Respons MEA dapat sebagai kontribusi yang membedakan pola kerja posisi berdiri TG, SDTS, dan SDPS ($p' < 0,05$). Pola koefisian respons MEA terhadap pola kerja bubut untuk posisi berdiri TG (laktat 4,853 mmol/kg, glukosa 0,221 mg %); posisi berdiri SDTS (laktat 3,100 mmol/kg , glukosa 0,175 mg %); dan SDPS (laktat 3,314 mmol/kg, glukosa 0,07089 mg %). Terdapat hubungan kuat antara tingkat kelelahan otot biomekanik (TKOB) dengan konsentrasi asam laktat dan glukosa ($R > 0,05$). TKOB antar kelompok kerja bubut adalah tidak sama ($p' <$

0,05). Terdapat hubungan antara perubahan letak TB dan TT kerja bubut posisi berdiri, perubahan sudut tubuh (PST), TKOB dan produktivitas kerja (R > 0.05).

Berdasarkan analisis data, dapat disimpulkan pertama, bahwa tenaga kerja bubut yang belum atau tidak melakukan aktivitas kerja, tidak mengalami perubahan konsentrasi asam laktat dan glukosa (p' > 0,05). Letak TB dan TT tubuh kerja bubut posisi berdiri TG mengalami metabolisme energi secara anaerobik lebih tinggi dibanding letak TB dan TT tubuh kerja bubut posisi berdiri SDTS maupun SDPS (p' < 0,05). Kedua, letak TB dan TT tubuh pada kerja bubut posisi berdiri TG membutuhkan intensitas kontraksi otot yang lebih besar dibanding letak TB dan TT kerja bubut posisi berdiri SDTS maupun SDPS (p' < 0,05). Ketiga, TKOB pada letak TB dan TT tubuh tenaga kerja bubut posisi berdiri TG lebih tinggi dibanding TKOB posisi berdiri SDTS, dan TKOB pada letak TB dan TT tubuh SDTS lebih tinggi dibanding TKOB posisi berdiri SDPS (p' < 0,05). Jadi letak TB dan TT tubuh kerja bubut posisi SDPS lebih tidak melelahkan (lebih nyaman) dibanding letak TB dan TT tubuh posisi berdiri TG maupun SDTS. Ke-empat, produktivitas kerja bubut pada letak TB dan TT tubuh SDTS dan SDPS secara signifikan adalah tidak beda (p > 0,05). Produktivitas kerja tenaga kerja bubut pada letak TB dan TT tubuh posisi berdiri SDTS dan SDPS lebih tinggi dibanding produktivitas kerja tenaga kerja bubut pada letak TB dan TT tubuh posisi berdiri TG (p' < 0,05). Oleh karena itu, disarankan bahwa perusahaan atau instansi yang mempekerjakan tenaga kerja dengan kerja posisi berdiri tegak statis agar diubah menjadi posisi berdiri setengah duduk yang dapat relaksasi sehingga dapat mengurangi kelelahan otot biomekanik dan dapat meningkatkan produktivitas kerja tenaga kerja.

EFFECT OF LOCATION CHANGE OF CENTER OF GRAVITY AND POINT OF SUPPORT IN THE BODY DURING STANDING LATHE WORKING ON BIOMECHANICAL MUSCULAR FATIQUE

(ERGONOMIC EXPERIMENTAL STUDY USING ANAEROBIC ENERGY METABOLISM APPROACH)

Gempur Santoso

SUMMARY

This study investigated the effect of location change of center of gravity (CG) and point of support (PS) in the body during standing lathe working on biomechanical muscular fatigue. Until today, workers who work in standing position often experience fatigue (Yassierli et al, 2000; Gempur, 2001), back pain (Duquette, 1997), and *lumbar lordosis* (Lord et al, 1997). Manual lathe working still carries out in upright standing (US) position. The change of location of CG and PS as mentioned above concerned with the change of location from upright standing (US) position to half-sitting with no support (HSWNS) standing position and half-sitting with support (HSWS) position. Biomechanical muscular fatigue was skeletal muscular fatigue measured using anaerobic energy metabolism (AEM) based on the concentrations of lactic acid and glucose.

The change of that position was aimed to obtain a more ergonomic standing to eliminate or reduce biomechanical muscular fatigue based on AEM concept, which was finally expected to increase working productivity.

This was an experimental study using pre- and post control group design, in which biomechanical muscular fatigue before and after working was measured in control group and in three treatment groups. Control group (C) consisted of lathe workers who did not perform lathe working or other activities, while the treatment groups were lathe workers who worked in US, HSWNS, and HSWS standing positions. The population was 60 participants of manual lathe working training in *Balai Latihan Kerja Industri dan Pengembangan* (BLKIP) Surabaya. Samples were selected using criteria and in random. From 60 subjects, those who met the criteria were 58, and 40 from which were enrolled in this study. They were divided into 4 groups, each consisted of 10 subjects. Four subjects in control group resigned, so that the size of control group became only 6, while those in treatment groups remained 10.

Results showed that AEM before working in those groups were similar ($p > 0.05$). However, AEM after working showed difference ($p < 0.05$). The AEM response between groups ($p < 0.05$) was different. AEM response might have contribution in differentiating working pattern in US, HSWNS, and HSWS standing position ($p < 0.05$). The coefficient pattern of AEM response on lathe working pattern for lactate and glucose for US was 4.853 mmol/kg and 0.221 mg%, HSWNS was 3.100 mmol/kg and 0.175 mg%, and HSWS 3.314 mmol/kg, and 0.07089 mg%. A strong correlation was found between biomechanic muscular fatigue level (BMFL) and the concentrations of lactic acid and glucose ($r > 0.05$). BMFL in lathe working groups was not similar ($p < 0.05$). A correlation was found between the change of CG and PS locations in standing lathe working, change of body angle (CBA), BMFL and working productivity ($r > 0.05$).

From the data analysis, it can be concluded that, first, lathe workers who have or did not performed any activities for 3 hours showed no change of lactic acid and glucose concentration ($p > 0,05$). The highest concentration of lactic acid and lowest concentration of glucose was found in lathe workers with US position, indicating that this position

resulted in higher metabolism of anaerobic energy compared to HSWNS and HSWS standing ($p < 0,05$). Second, lathe working with US position requires higher intensity of muscular concentration compared to HSWNS and HSWS standing ($p < 0,05$). Third, CG and PS location during lathe working in HSWS standing position results in higher comfort compared to that in US and HSWNS standing position. ($p < 0,05$). Fourth, results of lathe working productivity with CG and PS location in HSWS and HSWNS standing position was significantly similar ($p > 0,05$), but higher than that with CG and PS location in US standing position ($p < 0,05$). It is recommended that companies or institutions, whose workers have to work in static standing position, should change the position of their workers to half-sitting position which enable them to do some relaxations to reduce or eliminate biomechanical muscular fatigue and increase working productivity.

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ABSTRACT

This study investigated the effect of location change of center of gravity (CG) and point of support (PS) in the body during standing lathe working on biomechanical muscular fatigue. Until today, workers who work in standing position often experience biomechanical muscular fatigue. By redesigning PS and CG in lathe workers from upright standing (US) to half-sitting with no support (HSWNS) standing position and half-sitting with support (HSWS) position, a more ergonomic standing position could be obtained. Therefore, biomechanical muscular fatigue can be reduced based on the concept of anaerobic energy metabolism (AEM) in which the concentrations of lactic acid and glucose change, which is finally expected to increase working productivity.

This was an experimental study using pre- and post control group design. The population was 60 participants of manual lathe working training in *Balai Latihan Kerja Industri dan Pengembangan* (BLKIP) Surabaya. Samples were selected using criteria and in random. The sample size of US group was 10 subjects, HSWNS 10, HSWS 10, and Control 6 subjects.

Results showed that AEM before working in those groups were similar ($p > 0.05$). However, AEM after working showed difference ($p < 0.05$). The AEM response between groups ($p < 0.05$) was different. AEM response might have contribution in differentiating working pattern in US, HSWNS, and HSWS standing position ($p < 0.05$). A strong correlation was found between biomechanic muscular fatigue level (BMFL) and the concentrations of lactic acid and glucose ($R > 0.05$). BMFL in lathe working groups was not similar ($p < 0.05$). A correlation was found between the change of CG and PS locations in standing lathe working, change of body angle (CBA), BMFL and working productivity ($R > 0.05$).

It can be concluded that, first, lathe workers who have or did not performed any activities for 3 hours showed no change of lactic acid and glucose concentration. CG and PS locations during lathe working in US position had higher AEM than that in HSWNS and HSWS standing position. Second, CG and PS location during lathe working in US position requires higher muscular contractions than that in HSWNS and HSWS standing position. Third, CG and PS location during lathe working in HSWS standing position results in higher comfort compared to that in US and HSWNS standing position. Fourth, results of lathe working productivity with CG and PS location in HSWS and HSWNS standing position was significantly similar, but higher than that with CG and PS location in US standing position. It is recommended that companies or institutions, whose workers have to work in static standing position, should change the position of their workers to half-sitting position which enable them to be more relaxed to reduce biomechanical muscular fatigue and increase working productivity.

Keywords: *body center of gravity and point of support, lathe working, lactic acid, glucose, lactic acid response, glucose response, biomechanical muscular fatigue, working productivity, ergonomic*