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Original Article

Ergonomic Risk Assessment Tools and Postures During Lifting Tasks: A Systematic Research Review

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Abstract

Ergonomic risk factors such as awkward working posture has been associated with occupational injury and fatigue, especially in lifting tasks. This review was performed to analyze and summarize the studies about posture, ergonomic risk assessment tools and the activation of the muscle by EMG in lifting task. This review was carried out based on relevant articles published in PubMed, Science Direct, and Health Science Journals. Afterward, the outcomes were analyzed and narrative summarized by classification into four issues as 1. ergonomic risk assessment tools of lifting workers in industries**,** 2. postures of lifting, 3. posture assessment by goniometer and 4. muscle activation during lifting by measuring electromyography (EMG). The results showed that there were 20 research studies met the criteria from 276 enrolled citations and indicated that the REBA and NIOSH lifting equation were used in lifting task. Different working postures in lifting revealed that impact the parts of the body. Few studies were performed posture assessment and the most common method used to assess muscle activation was EMG in terms of identifying force and fatigue while working or after improved the workstation. The suggestion for further studies is that there should be considering both tools of self-report by subjective assessment and objective assessment by such ergonomics assessment tools and direct methods with
measurement in order to complete field study under real working conditions.

***Keywords*:** *Lifting, Rapid Entire Body Assessment, REBA, NIOSH Lifting, Goniometer, Electromyography (EMG)*

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นิพนธ์ต้นฉบับ

เครื่องมือประเมินความเสี่ยงทางการยศาสตร์และท่าทางขณะทำงานยก: การทบทวนงานวิจัยอย่างมีระบบ

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บทคัดย่อ

ปัจจัยเสี่ยงทางการยศาสตร์ เช่น การใช้ท่าทางที่ไม่เหมาะสม (Awkward posture) มีความสัมพันธ์กับการบาดเจ็บจากการทำงานและความเมื่อยล้าโดยเฉพาะอย่างยิ่งในงานยก การศึกษาครั้งนี้จึงมีวัตถุประสงค์เพื่อวิเคราะห์และสรุปรายงานการศึกษาที่ผ่านมาเกี่ยวกับท่าทาง เครื่องมือประเมินความเสี่ยงทางการยศาสตร์ และการทำงานของกล้ามเนื้อโดยใช้เครื่องตรวจวัดคลื่นไฟฟ้ากล้ามเนื้อ [Electromyography (EMG)] ในงานยก โดยทำการสืบค้นข้อมูลงานวิจัยที่ตีพิมพ์ในฐานข้อมูลอิเล็กทรอนิกส์ได้แก่ PubMed, Science Direct และ Health Science Journals หลังจากนั้นจึงนำผลการศึกษาที่ได้มาวิเคราะห์และสรุปเชิงเนื้อหา โดยแบ่งเป็น 4 ประเด็น ดังนี้ 1. เครื่องมือประเมินความเสี่ยงทางการยศาสตร์ในงานยกของพนักงานในโรงงานอุตสาหกรรม 2. ท่าทางในการยก 3. การประเมินท่าทางโดยใช้โกนิโอมิเตอร์ (Goniometer) และ 4. ภาระงานของกล้ามเนื้อในขณะทำงานยกโดยใช้เครื่องตรวจวัดคลื่นไฟฟ้ากล้ามเนื้อ (EMG) รายงานวิจัยที่ผ่านเกณฑ์ศึกษาจำนวน 20 เรื่องจากการค้นพบ 276 เรื่อง ผลการศึกษาพบว่า แบบประเมิน REBA และแบบประเมินความเสี่ยงงานยก NIOSH lifting equation ถูกใช้วิเคราะห์ความเสี่ยงทางการยศาสตร์ขณะทำงานยก ท่าทางการทำงานที่แตกต่างกันในขณะยกส่งผลต่อส่วนต่างๆ ของร่างกาย นอกจากนี้มียังพบการศึกษาในจำนวนที่น้อยเกี่ยวกับการประเมินท่าทาง และวิธีการศึกษาส่วนใหญ่ในการประเมินภาระงานของกล้ามเนื้อ คือ การใช้เครื่อง EMG ในการวิเคราะห์หาแรง (Force) และความล้า (Fatigue) ในขณะทำงานหรือหลังจากการปรับปรุงสถานีงาน การศึกษาในอนาคตควรเน้นในเรื่องการหาความสัมพันธ์ของการประเมินแบบรายงานด้วยตนเอง (Subjective assessment) หรือ การประเมินจากการสังเกต (Objective assessment) กับวิธีการวัดโดยตรง (Direct methods) เพื่อยืนยันผลการศึกษาในสภาพการทำงานยกที่เกิดขึ้นจริง

คำสำคัญ: *งานยก, Rapid Entire Body Assessment, REBA, NIOSH lifting, โกนิโอมิเตอร์, คลื่นไฟฟ้ากล้ามเนื้อ*

Introduction

Work-related musculoskeletal disorders (WMSDs) in industries currently become as a critical problem, especially occupational back injury and still increasingly both in Thailand and other countries (Heebgaew & Puttyangkura, 2016). According to the social security office Thailand in 2018, a number of Thai workers who suffer from injury or illness due to musculoskeletal disorders were 1,554 cases. Moreover, the causes of occupational injury is lifting, pulling or pushing over load are 636 cases as well as working posture were 381 cases (Social Security Office, 2018). These showed that the abnormality of the body due to work was mainly caused by lifting. Furthermore, inappropriate ergonomics such as force exertion, bending, twisting, repetitive tasks and awkward working posture can cause musculoskeletal health as a consequence result of illness and fatigue (Luttmann, Jager, & Griefahn, 2003).

Therefore, lifting can be risk of body pain causation of various factors, particularly in ergonomic factors. At present many studies indicate the varieties of assessment tools included subjective and objective assessments. In this study focused on objective assessments, the tools that frequently used to analyze lifting task were Rapid Entire Body Assessment (REBA) and NIOSH lifting equation which would be effective when used together to identify risks. To assure results from REBA and NIOSH lifting equation tools, direct measurement was another method for assessment of posture and force such as goniometer and electromyography (EMG). Goniometer is an instrument which directs measurement with subjects for assessment range of motion of body joints (Swann, 2012). Electromyography (EMG) is a diagnostic technique that measuring the electrical signal associated with the activation of the muscle. However, using EMG requires the selection of the muscle condition and features appropriately for the work (Nazmi et al., 2016).

Thus, it is very important to study for awkward working posture and the assessment tools associated with lifting task. Therefore, the purpose of this review was performed to summarize and analyze the studies about posture, ergonomic risk assessment tools and the activation of the muscle by EMG in lifting task.

Methodology

- **Searching methods**

An electronic search was conducted using PubMed, Science Direct, and Health Science Journals published from 2010 to 2018, as well as, focused on ergonomic risk assessment tools and the activation of the muscle by EMG in lifting task. The search keywords were as follows: Lifting, Rapid Entire Body Assessment, REBA, NIOSH lifting, Goniometer, Electromyography, EMG.

- **Selection of references**

References in English and Thai languages were retrieved for further studies. The search strategy included a combination of terms and synonyms for Lifting/REBA/NIOSH lifting/ goniometer/ Electromyography/EMG. The criteria of articles were as follows: 1) related to lifting task in workers 2) related to ergonomic risk assessment tools in workers 3) related to the measurement of goniometer and EMG 4) available in full-text in English or Thai, 5) published in journals or theses since 2010.

Results

The search strategy identified a total of 276 citations. A total of 37 were deemed potentially relevant at the first level of screening. Research of 20 studies that enrolled and met the criteria, were analyzed and narrative summarized by 6 studies were identified as ergonomic risk assessment

tools of lifting workers in industries, 5 studies as postures of lifting, 2 studies as posture assessment by goniometer and another 7 studies as muscle activation during lifting by measuring electromyography (EMG).

1. Ergonomic risk assessment tools of lifting workers in industries

In Table 1, the most widely use and appropriate ergonomics assessment tools in lifting task are REBA and NIOSH lifting equation. In the six studies analyzed, two of them chose combine between REBA and NIOSH lifting equation in distribution center and filling gas containers and automotive parts manufacturing workers in Thailand (Wichai & Chaiklieng, 2014; Heebgaew & Puttyangkura, 2016). In the other four studies, chosen only NIOSH lifting equation to assess risk in the stretch forming process, tire manufacturing, engine manufacturing, and process of arc stack medium workers (Balasubramanian, Sivapirakasam & Krishna, 2018; Songsungnoen & Pusapukdepob, 2013; Kamnuengthamkhuncha & Chantrasa, 2011; Waters et al., 2011).

2. Postures of lifting

Awkward working posture in lifting task is one of the ergonomic risks that have been associated with work- related musculoskeletal discomfort (fatigue) and leading to injury of the back and others (Chowdhury, Boricha & Rardi, 2012). This has been confirmed by five studied, in Table 2 most researchers investigated in different posture and designed experimental task in the laboratory (Hlavenka, Christner, & Gregory, 2017; Peolsson et al., 2014; Blache et al., 2014; Wang et al., 2012; Nimbarte et al., 2010). Only one study did not use electromyography (EMG) as a measurement to assess muscle activation but used ultrasound and speckle tracking analysis (Peolsson et al., 2014). The posture of lifting in five studies concluded squat, semi-squat, stoop, flexed, extended, forward head, retracted, freestyle, neutral position, shoulder and eye level. Back, neck and shoulder muscles were studied in these studies.

3. Postures assessment by goniometer

In the two studies, firstly studied in breast cancer patients by dividing two conditions as a control group was received usual care and case group was given shoulder exercise program in combination with qigong, the researcher assesses the degree of shoulder movement in 5 positions included flexion, extension, abduction, internal rotation and external rotation (Markdum, Thanasilp, & Pudtong, 2017). Another one study compared the smartphone inclinometer-based app and universal goniometer and assessed the elbow joint the direction of flexion, supination and pronation of forearm movements. (Behnoush et al., 2016). As a result, goniometer was used to assess posture specific to the range of motion of the joint (angle) as presented in Table 3.

4. Muscle activation during lifting by measuring electromyography (EMG)

For EMG measurements in terms of (Maximum voluntary contraction) %MVC or (Maximum voluntary electromyography) %MVE as presented in Table4, firstly the study of Hlavenka, Christner, & Gregory (2017) was performed in 16 lifts with 10 kg mass and used the retracted neck and freestyle posture, the result showed significantly in lumbar erector spine, external oblique and sternocleidomastoid muscles but dorsal neck and thoracic erector spinae muscles were significant decrease moreover found that internal oblique muscle was no difference. Additionally, the result of the study by Antwi-Afaria et al. (2017) revealed increased lifting weights significantly increased EMG activity and muscle fatigue of the biceps brachii (BB), brachioradialis (BR), lumbar erector spinae (LES), and medial

gastrocnemius (MG) muscles, but not the rectus femoris (RF) muscle, EMG activity and muscle fatigue rate of the LES muscle were higher than all other muscles, a significant difference of EMG activity of the RF and MG muscles was observed between lifting postures (stoop and squat lifting posture), however no significant difference of muscle fatigue was apparent ($p>0.05$).

Wang et al. (2012) confirmed that %MVE of stoop lifting increased more than squat and semi-squat technique respectively moreover, they showed the median frequency of squat more than semi-squat and stoop respectively. Furthermore, Al-Ashaik, Ramadan, Al-Saleh, & Khalaf (2015) evaluated frequencies of lifting in 1 lift/min and 5 lifts/min and the result showed that % MVC in 5 lifts/min more than 1 lift/min.

In three studies as follow reviewed about muscle fatigue found that the normalized mean power frequency (NMPF) for the eight muscles for the 4 and 8 kg weight lifts, a decrease in the slope signified the onset of muscle fatigue (Ahmad & Kim, 2018). Two studies revealed the slope of mean frequency (MNF) and median frequency (Hz.) in erector spinae, deltoid and trapezius muscles after improved the workstation by providing the new design was more increased than before, that means after improved the workstation muscle fatigue has been become lower (Sungkhapong, Pochana, & Auesujaridwong, 2010; Punkub, Ratanaarporn, & Wongthanasunthorn, 2010).

Interestingly, the collection and processing of EMG data to analyze muscle activation (%MVC or %MVE), most of the studies were recorded at bandpass filtered from range 10-1000 Hz, amplified and sampled the EMG inputs at 1024 and 2048 Hz. Additionally, in two studies that collect the slope of mean frequency (MNF) and median frequency (Hz.) they were recorded EMG data in 2 hours and every hour.

Discussions

Previous studies and reviews have reported an association between different postures of lifting and impact of parts of the body, especially in neck, shoulder and back. As well, these studies did the same outcomes that were muscle activation, force and fatigue. Moreover awkward postures are a one of ergonomics risks.

Ergonomics assessment tools which appropriate tools for the heavy dynamic tasks were REBA and NIOSH (Poochada & Chaiklieng, 2016). REBA is appropriate for the posture assessment with lots of movements while working to know the ergonomic problem at work and more detailed than NIOSH. NIOSH considers the weight lifting and posture that workers can lift. Therefore, lifting task is a manual material handling and also heavy dynamic tasks that should consider not only weight lifting but also the posture for whole body. Similarly, the results of previous study, demonstrated consistent with two methods of ergonomic risk assessment (Wichai & Chaiklieng, 2014).

This review also described direct measurement for assessment of posture and force. All previous studies used goniometer for evaluating posture and an outcome was range of motion (degree). However, measuring of range of motion can record by video with software and identify of posture position for a specific task such as lifting task (Eungpinichpong et al., 2013). Regarding EMG results, although there were differences in the study outcomes because of different conditions and specific EMG methodology follow by research objectives.

Conclusion

REBA and NIOSH lifting equation are suitable of ergonomic risk assessment tools for lifting task. Furthermore, different posture or awkward working postures are factors that relate to musculoskeletal disorder which assess by goniometer for posture and confirm force or fatigue by EMG measurement. These are the tools for protection of occupational injury. In future, a prospective study should extend the issue about weight lifting and the association of objective assessments with direct measurement and subjective assessment. Some limitations in this study were; 1) The presentation of this review were uncovered several studies about other posture assessments except using goniometer in lifting task 2) Searching data bases is limited for the most comprehensive research that suggesting for searching from many databases.

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Table 1 Ergonomic risk assessment tools of lifting workers in industries

Researcher, year	Ergonomic risk assessment tools	Workers
Heebgaew & Puttyangkura (2016)	REBA and NIOSH lifting equation	Automotive parts manufacturing
Wichai & Chaiklieng (2014)		Distribution center and filling gas containers
Balasubramanian, Sivapirakasam, & Krishna (2018)		The stretch forming process
Songsungnoen & Pusapukdepob (2013)	NIOSH lifting equation	Tire manufacturing
Kamnuengthamkhuncha & Chantrasa (2011)		Engine manufacturing
Waters et al. (2011)		Process of arc stack medium

Table 2 Posture of lifting

Reference	Posture of lifting	Measurements	Result
Wang et al. (2012)	1) Squat 2) Semi-squat 3) Stoop	EMG	- MVE%: stoop> squat> semi-squat - MF (median frequency) : squat > semi-squat-> stoop
Peolsson et al. (2014)	1) Flexed 2) Forward Head 3) Neutral	Ultrasound recordings and speckle tracking analysis	Muscle deformation induced by flexed and forward head postures, compared to the neutral posture, for all dorsal neck muscles at rest.
Nimbarte et al. (2010)	1) Extended 2) Neutral 3) Flexed	EMG	- Sternocleidomastoid muscle: most active at the extended neck posture. - Upper trapezius muscle: most active at the flexed neck posture.
Hlavenka, Christner, & Gregory (2017)	1) Retracted 2) Freestyle	EMG	The retracted neck resulted in - Less lumbar spine flexion and increased lumbar erector spinae, external oblique, and sternocleidomastoid activity. - Decreased activity in the thoracic erector spinae and dorsal neck musculature.
Blache et al. (2014)	1) Shoulder level (H1) 2) Eye level (H2)	EMG	- The upper trapezius, supraspinatus, and infraspinatus were increased between H1 and H2 - The mean force produced by the anterior deltoid and subscapularis decreased between H1 and H2

Table 3 Posture assessment by goniometer

Reference	Sample	Condition	Assessment
Markdum, Thanasilp, & Pudtong (2017)	Breast cancer patients Case (n=25), Control (n=26)	Control group: receiving usual care Case group: shoulder exercise program in combination with qigong	Assess the degree of shoulder movement in 5 positions: flexion, extension, abduction, internal rotation and external rotation.
Behnoush et al. (2016)	Healthy subjects (n=60)	- Flex his/her elbow. - For supination and pronation: the wrist strap was used. The forearm was placed between these two positions and the palm was toward the body and thumb was located at 90˚ status. - For supination and pronation evaluations by goniometer, a pen was gripped in the subject hand to detect the axis better and the fixed arm was located on this axis.	- Compare the smartphone inclinometer-based app and universal goniometer. - The elbow joint: flexion, supination and pronation of forearm movements.

Table 4 Muscle activation during lifting by measuring electromyography (EMG)

Reference	Muscles	Values	EMG Data	Condition	Result
Hlavenka, Christner, & Gregory (2017)	1) Thoracic erector spinae (TES) 2) Lumbar erector spine (LES) 3) External oblique (EO) 4) Internal oblique (IO) 5) Sternocleidomastoid (SCM) Dorsal neck (splenius capitis and upper trapezius)	% MVC	- Band pass filtered from 10-1000 Hz - Amplified and sampled at 2048 Hz	**Position** 1) Mid-lift position using the retracted neck posture 2) Mid-lift position using the freestyle lifting posture. **Performed 16 lifts with a 10 kg mass** - Eight lifts: retracted - Eight lifts: freestyle	- The retracted neck posture Significant greater: LES (p<0.0001), EO (p<0.0001), SCM (p=0.022) Significant decrease: Dorsal neck (p<0.0001) TES (p = 0.004) No difference: IO (p=0.21)
Antwi-Afaria et al. (2017)	1) Biceps brachii (BB) 2) Brachioradialis (BR) 3) Lumbar erector spinae (LES) 4) Rectus femoris (RF) 5) Medial gastrocnemius (MG).	% MVC	- Band pass filter of 20–500 Hz.	1) Lifting of three different weights using either a stoop or squat lifting posture - 5%-, 10%-, and 15% of participant's maximum lifting strength (MLS). 2) A wooden box (measuring 30× 30× 25 cm and containing dumbbell weights)	Muscle activity of all muscles (BB, BR, LES, RF, and MG) increased with lifting weight - LES muscle showed the highest mean sEMG activity - RF muscle showed the lowest sEMG activity
Al-Ashaik, Ramadan, Al-Saleh, & Khalaf (2015)	1) Biceps brachii 2) Anterior deltoid 3) Trapezius 4) Erector spinae	% MVC	- Band pass filtered 20-500 Hz - The average mode and time interval of 0.1s - The sampling rate of 1000 Hz	1) Two-handle box (40 cm x 60 cm x 22 cm) having the weights inside. 2) The frequencies were 1 and 5 lifts/min 3) Three types of safety shoes: light-duty, medium-duty and heavy-duty safety shoes.	% MVC: 1 lift/min / 5lifts/min Biceps brachii: Significantly lower; light-duty safety shoes than heavy-duty safety, p<0.04 / Significantly lower; medium-duty safety shoes than heavy duty safety shoes, p<0.01. Anterior deltoid: Mean (S.D.)= 22.4% (8.5%)) / Mean (S.D.)= 37.2% (16.2%)) Erector spinae: Mean (S.D.)= 73.9% (4.0%) / Mean (S.D.)= 85% (3.3%).
Wang et al. (2012)	Paravertebral erector muscles	- %MVE - Median Frequency	- The sampling rate was 1024 Hz. - The low and high cut off frequency was 1 Hz and 1000 Hz.	1) A wooden box (36 cm×26 cm×28 cm) and a platform with adjustable height. 2) Lifting techniques: Stoop-, squat-, semi-squat-lifting	- MVE% : stoop> squat> semi-squat (P<0.05) - MF (median frequency) : squat > semi-squat> stoop (P<0.05)

Table 4 Muscle activation during lifting by measuring electromyography (EMG) (ต่อ)

Reference	Muscles	Values	EMG Data	Condition	Result
Ahmad & Kim (2018)	1) Bicep femoris (BF) 2) Vastus lateralis (VL) 3) Anterior deltoid (AD) 4) Rectus femoris (RF) 5) Middle deltoid (MD) 6) Upper trapezius (UT) 7) Gastrocnemius medialis (GS) 8) supraspinatus (SP)	Normalize mean power frequency (NMPF)	- Band pass filtered with frequencies of 10–500 Hz. - A sampling rate of 1024 Hz. - Signals were sampled at 1024 Hz.	1) A box (32(width)x 40(length)x 25(height)cm) 2) Each subject performed 24 sets of squats with a ten-second rest interval between each squat for 4 and 8 kg weights, respectively.	The NMPF for the eight muscles for the 4 and 8 kg weight lifts decreased in the slope that signified the onset of muscle fatigue.
Sungkhapon, Pochana, & Auesujaridwong (2013)	1) Erector Spinae (ES) 2) Anterior Deltoid (AD) 3) Trapezius	Mean Frequency (MNF)	Measure muscular fatigue by 2 hours between 9.00 a.m.–11 a.m.	Improved the workstation or tool follow by anthropometric data	After improved the workstation by providing the new design was more increased MNF than before.
Punkub, Ratanaarporn, & Wongthanasunthorn (2010)	1) Deltoideus muscle 2) Erector spinae	Median Frequency (MF)	Measure muscular fatigue by every hour between 8.00 a.m.–5 p.m.	Improved the workstation by providing the new design which is suitable to the physical bodies of the worker.	After improved the workstation by providing the new design was more increased MF than before.