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Prevalence of low back disorders among female workers and biomechanical limits on the handling of load and patients

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Abstract. The purpose of this investigation was to determine the association between prevalence of low back disorders in female workers and biomechanical demands of compressive and shear forces at the lumbar spine. A descriptive, cross-sectional and correlational study was carried out in 11 groups of female workers in the Province of Concepción. An interview was performed to investigate the prevalence of low back pain. To estimate biomechanical demands on the lumbar spine, it was used the 3DSSPP software. The Pearson correlation coefficient between the prevalence of low back disorders and peak compression force at the lumbar spine was r = ($p<0.005$). The Spearman correlation coefficient between the prevalence of low back disorders and peak shear force was r = 0.9 ($p <0.005$). To protect 90% of female workers studied, the limits of compression and shear forces should be at 2.8 kN and 0.3 kN, respectively. These values differ from the recommendations currently used, 3.4 kN for peak compression force and 0.5 kN for peak shear force.

Keywords: low back pain, women, handling load, compression force, shear force

1. Introduction

Musculoskeletal diseases (MDs) are among the most frequent health problems in the international labor population [1,11,19,21]. In Chilean workers similar tendencies have been described [3,10]. On the specific case of women there are antecedents that suggest that MDs in both lumbar spine and upper limbs constitute the most relevant causes of sick leave in female workers [4,14,16]. Within this context there is epidemiological evidence that associates mechanical demands of the manual handling load (MHL) with low back disorders [18]. Related to criteria of biomechanical stress used to assess risk of low back disorders, one of the indicators most referred corresponds to the peak compression force at lumbar region [7,13,22]. This force acts parallel to the longitudinal axis of the vertebral spine and it is calculated in procedures of highest mechanical load in the lumbar region during the workday [8]. Assessment methods correspond to both static and dynamic models. Static models are based on the calculation of compression forces as the sum of torques generated by the force of gravity acting on the mass centers of the body segments and on the load [7]. On the other hand dynamic models incorporate forces generated as a product of displacement and acceleration of both body segments and load [6]. These investigations have sustained the development of biomechanical criteria which along with references to physiological and psychophysical capabilities have allowed implementing methods such as NIOSH equation [22] and ISO 11228-1:2003 and EN 1005-2: 2004 norms, for the evaluation of weight limits that both men and women can manipulate.

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About limits of compression forces acting on lumbar region, the most used criterion for adults of both genders corresponds to that one described by NIOSH (22). In this sense, the experts committee who revised the epidemiological evidence that sustained the NIOSH equation [22], establishes 3,4 kN as intradiscal compression limit at lumbar 5 and sacral 1 joint. Studies that sustain this limit [6,22] and particularly the association background between frequency of lumbar injuries and intradiscal compression have been made mainly in male workers. However, if investigations on resistance to lumbar spine segments rupture are analyzed, these indicate that the maximum force tolerated by vertebral and intervertebral discs depends of the gender, age, cross section of discs and vertebral bodies [15]. Thus, average resistances to lumbar segment ruptures of 5.7 kN for men and 3.9 kN for women have been estimated. According to these references the intradiscal compression limit estimated for women is 2.69 kN [2]. This is the only reference described for women and its estimation is based on acceptable risk limits of low back by compression force at lumbar spine for adult males and its extrapolation to women as a function of the difference in the resistance of lumbar segments to rupture.

Another indicator of biomechanical stress associated to risk of low back disorders is the shear force [20]. This force acts in an anteroposterior way, parallel to the plateau of vertebral bodies and tends to displace one vertebra respect to another located in the immediate inferior level in the functional units of the vertebral spine. About the limits of peak shear force for lumbar spine, references are mentioned around 0.5 kN [8,20]. No reference values differentiated by gender are described for this indicator.

Based on the issues described above and also due to the lack of epidemiological evidence for the female gender, the aim of this research was to determine the association between prevalence of low back disorders in female workers and biomechanical demands of compressive and shear forces at the lumbar spine.

2. Methods

Study design and participants**:** Descriptive, cross-sectional and correlational study was carried out in eleven groups of female workers who performed activities related to manipulation of load or patients in companies or institutions located in the Concepción Province, Chile. The jobs studied corresponded to workers of salmon fillets trimming and packing in a frozen sea products company; patients care technicians (PCTs) of emergency service, surgery service, private ward service and cleaner in a public hospital; supermarket clerks and tellers; text borrowers in a university library; workers in charge of washing material and harvesting of nursery plants in a laboratory of the forest sector. The election of the studied labor activities was performed considering relative importance of musculoskeletal morbidity of female workers in the Concepción Province [4]. Study design was approved by the ethics committee of the University of Concepción.

Informed consent and survey: The research considered, in the first instance, the verification of the informed consent of participants. A study was carried to determine the prevalence of low back disorders. Through an interview, lumbar spine disorders that in the last 12 months had generated at least one day of sick leave were recorded. Lumbar spine disorders were classified according to CIE–10 [23]. In the survey applied to the workers age, time of work in the job and the extension of work day and week were required. About anthropometric variables, weight with a Detecto balance and stature with a Holtain Ltd. anthropometer were recorded for every worker.

Study on labor demands: To establish the magnitude of the required forces and the working postures in the handling of load and patients a time studies and movement were carried out. On this respect, through the work day, one to two hours of follow-up was performed to a 50% of the workers of every job studied. On the other hand, to establish the required forces in the different labors studied the points in which the loads were handled were determined, dynamometers were fixed and the magnitude of the forces used during handling products and objects were recorded. On the PCTs, during the time study, staff was asked about antecedents on the weight of the patients assisted. The number of PCTs that performed the procedures of patient handling was also recorded. In order to establish the forces required, handling persons as a function of the number of PCTs recorded in the time studies were simulated. The analysis identified areas of the body where the patients were handled and using harnesses to which were fixed dynamometers, there were determined the demands of forces.

Related to the work posture during the time studies using digital video cameras, positions adopted during manipulation of load were recorded. If the tasks were

cyclical 10 minutes recordings were made for every worker. In the jobs where handling tasks were not cyclical, during the time study all tasks that required manual manipulation of load were recorded by video camera. Posture study was complemented with a characterization of the work stations. Thus, height, width and depth of the work stations were measured in order to define the height over the floor and the horizontal distance of handling load.

As biomechanical stress indicators for the lumbar spine, peak compression and shear force at lumbar 5 and sacral 1 joint were used [7]. To estimate these indicators 3DSSPP software from Michigan University was used [7]. Procedure utilized consisted in identifying through the time study, tasks that required manipulation of load and patients and the associated forces. In every task and using video footages the greatest mechanical overload for the lumbar spine was determined. From the images deployed on the screen, angles of the different body segments in frontal and sagittal plane were verified [5]. 3D SSPP software was fed with this information and the peak compression and anteroposterior shear force for a woman that represents the 50 percentile for each job studied was calculated.

Statistical analysis**:** in order to select the most suitable analyses procedures, normality of the variables by means of the Kolmogorov–Smirnov goodness of fit test was evaluated. In the characterization of the people variables, particularly age, weight and height central tendency and dispersion indicators were used. Association among the prevalence of low back diseases, force required during the manipulation of load, work posture, peak compression and shear forces was determined. Association among variables with normal distribution was established by means of the Pearson coefficient and Spearman was used where no normal distribution could be assumed. Significance level used was $p<0.05$. For the analyses, STATISTICA 6.0 software was used.

3. Results

The total amount of workers studied was 140 participants. Age, weight and height characteristics are described in Table 1. In Table 2 the prevalence of low back disorders of the eleven groups studied are summarized. From the 16 registered cases, one of them corresponded to lumbago with sciatica and the other 15 were lumbago. Table 3 summarizes peak compression and shear forces on lumbar 5 – sacral 1 joint, in task and phase that generates greatest mechanical overload for lumbar spine. Values correspond to workers that represent the 50 percentile of body size of the groups studied. Table 4 describes Pearson and Spearman correlation coefficients between prevalence of low back disorders and biomechanical demands derived from the manual handling of load and patients.

Table 1

Age, weight and height of the eleven groups of female workers studied. Average values are described and, in parenthesis, standard deviation.

Groups	n	Age (years)	Weight (kg)	Height (m)
Trimming operators	8	37.4 (6.2)	73.4 (7.3)	1.60 (0.03)
Supermarket tellers	15	34.5 (7.6)	63.4 (6.2)	1.57 (0.05)
Library workers	9	46.2 (8.7)	65.7 (6.9)	1.56 (0.06)
Harvesting workers	16	33.2 (7.8)	61.9 (6.7)	1.55 (0.06)
PCTs of surgery	21	32.5 (6.7)	60.0 (7.0)	1.54 (0.04)
Stock clerks	9	34.1 (8.6)	61.4 (4.1)	1.55 (0.07)
Cleaners of surgery	7	44.1 (12.7)	60.8 (6.7)	1.55 (0.06)
Stuff lab washing workers	7	34.3 (8.0)	62.5 (6.5)	1.56 (0.09)
Packing workers	18	38.2 (5.6)	66.6 (6.7)	1.59 (0.05)
PCTs of private ward	8	35.5 (7.1)	58.6 (7.4)	1.57 (0.06)
PCTs of emergency	22	39.3 (7.2)	70.7 (10.2)	1.59 (0.09)

n: number of workers

4. Discussion

According to the Table 4, the force required for handling load explains part of the tendency of the prevalence of low back disorders. The correlation coefficient between the forces required in the manipulation of load and prevalence is $r = 0.84$ ($p<0.005$). However, low back disorders have better association to peak compression and shear forces indicators, which reach correlation coefficients of $r = 0.9$ ($p<0.005$). These biomechanical stress indicators integrate the effect of the weight of head, trunk and upper limbs, the weight of the load, the force re-

quired for the manipulation of the load and the work posture.

About tolerable limits of compression forces acting on lumbar region, it has been mentioned that 3.4 kN is the criterion currently used as reference [22]. In this way the linear regression equation obtained for the association between prevalence of low back disorders (PLBD) and peak compression force (PCF) is: PLBD = -16.698 + 9.4 (PCF), with a standard error of Syx = 4.6%. Thus, when the equation is used and the reference peak compression of 3.4 kN is entered, the estimated prevalence of lumbar disorders for the studied workers is 15.3%. Within this context, it is necessary to define the percentage of the working population to be protected by tolerable limits of peak compression acting on lumbar region.

Table 2
Prevalence of low back disorders (lumbago and lumbago with sciatica) of eleven groups of female workers studied.

Groups	Prevalence of Low back disorders (%)
Trimming operators	0
Supermarket tellers	0
Library workers	0
Harvesting workers	0
PCTs of Surgery	9.5
Stock clerks	11.1
Cleaners of surgery	14.3
Stuff lab washing workers	14.3
Packing workers	16.7
PCTs private ward	25.0
PCTs of emergency	27.3

On this respect, the European Norm EN 1005-2: 2004, which is based in biomechanical, physiological and epidemiological basis, establish criterion to protect between 70% and 99% of the working population. This norm considers criteria to define maximum weights that provide better protection to different groups of workers. In the specific case of females and for general working population, the recommendation would allow to protect to 90% of this population.

Table 3
Peak compression and shear forces in lumbar 5 – sacral 1 joint in the task and phase that generates greatest mechanical overload for lumbar spine.

Groups	Peak compression force (kN)	Peak shear force (kN)
Trimming operators	1.4	0.14
Supermarket tellers	1.5	0.14
Library workers	2.1	0.27
Harvesting workers	2.2	0.23
PCTs of Surgery	3.5	0.35
Stock clerks	3.0	0.37
Cleaners of surgery	3.5	0.35
Stuff lab washing workers	3.6	0.36
Packing workers	3.4	0.36
PCTs private ward	4.2	0.41
PCTs of emergency	3.7	0.39

Table 4
Pearson and Spearman correlation coefficients between prevalence of low back disorders and biomechanical demands derived from the manual handling of load and patients.

Correlation	Biomechanical variables in the greatest overload task	Prevalence low back disorders (%)	P
Pearson	Trunk flexion (degrees)	0.24	ns
	Required force (kgf)	0.84	0.001
	Peak compression force (kN)	0.90	0.0002
Spearman	Peak shear force (kN)	0.90	0.0002

Based on these antecedents and by using the linear described above, it was estimated that for a preva-

lence of low back disorders (PLBD) of 10% and therefore protecting 90% of the female workers studied, the peak compression force reaches 2.8 kN. This peak compression value is similar and consistent with the value of 2.69%, the only bibliographic reference identified for the feminine gender [2].

With respect to peak shear force, there is a lack of antecedents to define acceptable limits. In this way, the most referred criterion is 0.5 kN [8,20]. If this value is compared to the results of this investigation, from table 3 it can be deduced that 0.5 kN exceeded all peak shear forces registered in the eleven jobs studied. For the jobs that presented cases with low back disorders, the average peak shear force is 0.37 kN ranging from 0.35 kN to 0.41 kN. In the jobs without cases of low back disorders, the average peak shear force is 0.2 kN, ranging from 0.14 to 0.27 kN. About tolerable biomechanical limits, if prevalence of lumbar disorders is close to 10%, it is possible to identify two jobs studied with prevalence around that value, there are 9.5% and 11.1%. These jobs registered peak shear forces of 0.35 kN and 0.37 kN respectively. In addition, the relation between the prevalence of low back disorders (PLBD) and peak shear force (PSF) presented an exponential tendency. The equation for this relation is $PLBD = 0.09e^{(13.9684 \text{ x } PSF)}$. Thus, from the equation it was possible to determine that a PSF of 0.34 kN generates a PLBD of 10%; limit that would allow to protect up to 90% of the female workers studied.

5. Conclusions

As it can be deduced, there is a discrepancy between the limits of both peak compression and shear forces currently used as reference to assess low back disorders derived from handling load and the limits studied in this study. Thus, complementary epidemiological studies must be carried out in order to allow providing consistency to the definition of tolerable biomechanical limits for the feminine gender in tasks of handling both load and patients.

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References

[1] Agencia Europea para la Seguridad y la Salud en el Trabajo. 2006. Informe Anual. [Citado 18 Octubre 2009]. Available in: http://osha.europa.eu/es/publications/annual_report/2006

[2] A. Mital, A. Nicholson and M. Ayoub M. A Guide to manual material handling. London: Taylor & Francis, 1997.

[3] Asociación Chilena de Seguridad, Anuario Estadístico, 2006. [Citado 18 Octubre 2009]. Available in http://www.achs.cl

[4] A. Torres and T. Paravic. Morbilidad de la mujer trabajadora, Servicio de Salud Concepción, Chile. Cienc enferm. 11 (2005), 73-84.

[5] C. Norkin and D. Wite. Measurement of joint motion: A guide to goniometry. 3ª ed. Philadelphia: F.A. Davis, 2003.

[6] D. Chaffin and K. Park, 1973. A longitudinal study of low-back pain as associated with occupational weigth lifting factors. Am Ind Hyg Assoc J. 34 (1973), 513-525.

[7] D. Chaffin, G. Andersson and B. Martin. Occupational Biomechanics. New York: John Wile and Sons, 2006.

[8] D. Daynard, A. Yassi, J. Cooper, R. Tate, R. Norman and R. Wells R. Biomechanical analysis of peak and cumlative spinal loads during simulated patient-handlig activities: a substudy of randomized trial to prevent lift and transfer injury of health care workers. Appl Ergon. 32 (2001), 199-214.

[9] European Norm-EN 1005-2. Seguridad de las máquinas. Comportamiento físico del ser humano. Parte 2: Manejo de máquinas y sus componentes, 2004.

[10] E. León,N. Siervo and I. Urzúa . 2004. Enfermedades profesionales: Un desafió presente y futuro. Segur Acción. 72(2004), 17-20.

[11] F. Benavides, J. Delclos, J. Benach and C. Serra. Lesiones por accidente de trabajo, una prioridad en salud pública. Rev Esp Salud Pública. 80 (2006), 553-565.

[12] International Standard Organization-ISO. ISO 11228-1. Ergonomics. Manual handling:Part 1: Lifting and carrying, 2003.

[13] M. Ayoub and A.Mital A. 1989. Manual material handling. London: Taylor & Francis.

[14] M. Gutiérrez, C. Flores, A. Chesta, N. Jofré, K. Brito and J. Monzó. Capacidad de manejo de carga de trabajadoras y regulación de peso máximo de carga humana – Ley Nº 20.001. Rev Prev Riesgos. 79 (2008), 24-28.

[15] M. Jager and A. Luttmann. Compressive strength of lumbar spine elements related to age, gender, and other influencing factors. J Electromyography Kinesiol.2 (1991) 291-294.

[16] M. Pérez. Prevalencia de enfermedades profesionales con dictamen de invalidez, Región Metropolitana, años 2005 – 2006. Cienc Trab. 30 (2008), 113-119.

[17] National Institute for Ocuppational Safety and Health (NIOSH). Application manual for the revised NIOSH lifting equation. Publication N° 94-110. U.S. Department of Health and human services. Cincinnati, 1994.

[18] National Institute for Ocuppational Safety and Health (NIOSH). Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back. Publication N° 97-141. U.S. Department of Health and human services. Cincinnati, 1997.

[19] Organización Internacional del Trabajo. Enciclopedia de Salud y Seguridad en el Trabajo: Sistema músculo esquelético, 1998. [Citado 18 Octubre 2009]. Available in: http://www.insht.es/InshtWeb/Contenidos/Documentacion/TextosOnline/EnciclopediaOIT/tomo1/6.pdf

[20] R. Norman, R. Wells, P. Neumann, J. Frank, H. Shannon and M. Kerr M. A comparison of peak vs cumulative physical

loading factors for reported low back pain in the automobile industry. Clin Biomech. 13 (1998), 561-573.

[21] U.S. Department of Labor. U.S. Bureau of Labor Statistics, 2007. [Citado 18 Octubre 2009]. Available in: http://www.bls.gov/iif/oshwc/osh/os/osh06_37.pdf

[22] T. Waters, V. Putz-Anderson, A. Garg and L. Fine. Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics. 36(1993): 749-776.

[23] World Health Organization. International Statistical Classification of Diseases and Releted Health Problems 10th Revision, 2007 [citado 30 de octubre 2009] Available in: http://www.who.int/classifications/icd/en/.