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Ergonomic Risk Factor Assessment and Mitigation for Employees at a University Gym

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Abstract: Previous research has demonstrated that approximately 3.2 out of every 100 fitness and recreational employees sustain injuries due to ill-suited administrative and engineering controls. The purpose for this case study was to assess ergonomic risk factors for employees at a university gym, and to develop recommendations for reducing the likelihood of musculoskeletal disorders (MSDs). The three most frequently performed tasks were evaluated including weight re-racking, cleaning the fitness equipment, and registering gym members. Questionnaire and video data were collected and analyzed for two employees using the BodyMap assessment, the Rapid Upper Limb Assessment (RULA), and the NIOSH Lifting Index. Additionally, employee anthropometric data and workstation dimensions were recorded.

The employee who performed the weight re-racking task reported frequent (few times/week to everyday) and very uncomfortable levels of discomfort (range: 2 - 8, M = 3.92) on the BodyMap assessment, and had NIOSH Lifting Indices ranging from 0.32 - 3.84 (M = 1.79), suggesting that this task increased the risk of injury and should be redesigned. It was recommended that training protocol, an administrative change, be implemented to educate the employees about proper lifting techniques such as lifting from the legs instead of the back. The employee who performed the cleaning task exhibited twisting and flexion of the back and had RULA values of four and five for the left and right upper extremities, respectively. Administrative controls, such as standard operating procedures highlighting the importance of sidestepping instead of twisting and flexing the back were recommended for mitigation. Lastly, the employee who registered gym members did so approximately once per minute, which caused static loading of the right arm, right shoulder flexion (>25 degrees), and right wrist extension (>30 degrees). It was recommended that administrative and engineering changes be made including modifying the existing workstation and changing the nature of the registration task.

Keywords: case study, ergonomic assessment, musculoskeletal disorders

1. Introduction

Although the physical risk for employees at fitness centers is somewhat low (Posner, 2000), previous investigations have found that injuries can nonetheless occur without suitable administrative and engineering controls (Olsen, Hudson, & Thompson, 2008). In particular, employees who regularly interact with weight equipment (e.g., returning weights to their racks, cleaning exercise benches) may be at an elevated risk for musculoskeletal disorders (MSDs). Some common MSD risk factors for these employees include inappropriate, repetitive bending or lifting, for exertion as low as 2% of maximum capacity (Silverstein, 1986; Westgaard & Winkel, 1996). Similarly, gym employees who perform seated work in the reception area may have an elevated risk for lower-back and soft tissue injuries common among office employees (Burton, 1997). These injuries and others represent a threat to employee well-being and to the financial viability of their employer. However, there is limited research evaluating ergonomic risk factors for fitness center employees. Therefore, the goal for this case study was to develop recommendations to mitigate the ergonomic risk factors associated with the three most frequently performed tasks.

The current ergonomic assessment was conducted at the Skyline Fitness Center at George Mason University. This facility is staffed with 16 employees who perform a variety of maintenance and administrative tasks. We assessed the three most frequently performed tasks including weight re-racking, cleaning fitness equipment, and registering gym members. The weight re-racking task involved lifting 2.5 to 45 pound weights from the ground, carrying these plates to the weight rack, and placing them onto the rack. The second task evaluated was cleaning the fitness equipment. This equipment consisted of padded benches that either stand alone or are attached to cable-weight equipment. In either case, the process of cleaning consisted of spraying the surface with a cleaning liquid and wiping it dry with a hand towel. The third task evaluated was registering gym members to allow them to access the facilities, which was performed at a seated workstation. To register gym members, the employee must either stand or reach for each person's membership card, verify the information on the card, swipe the membership card using a device located on the work surface, and return the card.

2. Method

2.1 Participants

Two participants employed at George Mason University's Skyline Fitness Center participated in this case study. The employee who maintained and cleaned the fitness equipment (floor employee) was 21 years of age, weighed 205 pounds, and was 68 inches (5'8") tall. The employee who registered gym members (reception employee) was 20 years of age, weighed 120 pounds, and was 64 inches (5'4") tall. Both employees reported that they worked 12 hours per week and had held their respective positions for just over a year.

To ensure that injury reports stemmed from work-related rather than personal activities, we collected information on the daily habits and hobbies of each employee. The employees indicated that they performed several physical activities outside of work. The floor employee reported playing basketball regularly. This employee also reported that he had a history of painful shin splints. The reception employee reported that she exercised regularly. Neither employee reported a history of chronic pain disorders or disabilities (e.g., carpal tunnel syndrome, ganglionic cysts, tendonitis, etc.).

2.2 Materials and Procedure

Ergonomics risk factors were evaluated for the three most commonly performed tasks: weight re-racking, cleaning fitness equipment, and registering gym members. The materials used in this case study were the BodyMap Assessment (Marley & Kumar, 1996), the Rapid Upper Limb Assessment (RULA; McAtamney & Corlett, 1993), the NIOSH Lifting Index (Waters & Putz-Anderson, 1991), and the Office Ergonomics Evaluation (Fernandez & Marley, 2013). Lastly, we interviewed the two employees and video taped them while they worked.

2.2.1 BodyMap Assessment

Marley and Kumar (1996) created the BodyMap assessment to assess physical symptoms of discomfort experienced within the previous 30 days. For this measure, the employees were asked to indicate the areas of discomfort and the frequency and levels of discomfort. Level of discomfort was rated using a 10-point scale ranging from *no discomfort* (0) to *extreme discomfort* (10). The frequency of discomfort was recorded using a 4-point scale ranging from *never* (0) to *constantly* (3). The scores on both scales were evaluated using the BodyMap scoring sheet resulting in four potential outcomes: "green zone - not likely to seek treatment, yellow zone - somewhat likely to seek treatment, red zone - very likely to seek treatment, and infeasible zone (no recordings)" (Marley & Kumar, 1996).

2.2.2 Rapid Upper Limb Assessment (RULA)

The RULA (McAtamney & Corlett, 1993) was used to assess the level of upper limb risks for both employees. For this assessment, posture is rated for the upper arms, lower arms, wrists, wrist twists, and neck. Then, muscle and force were assigned scores using the scoring table. Finally, a grand score was calculated for the left and right upper limbs. A score ranging from 1 - 2 was classified as *posture acceptable if not maintained or repeated for long periods*, 3 – 4 was classified as *further investigation is needed, and changes may be required*, 5 – 6 was classified as *investigation and changes are required soon*, and a score of 7 was classified as *investigation and changes are required immediately*.

2.2.3 NIOSH Lifting Index

The NIOSH 1991 Lifting Index was calculated for the employee who re-racked weights to assess the physical stress associated with manual lifting (Waters & Putz-Anderson, 1991). A lifting index > 1 represented a high-risk task, and controls are recommended to decrease this risk.

2.2.4 Office Ergonomics Evaluation

The physical dimensions of the workstations and anthropometric measurements were collected using the Office Ergonomics Evaluation form (Fernandez & Marley, 2013, pp. 185-186). The anthropometric measurements for the floor employee were recorded in a standing posture because this employee stood for the duration of his shift. The dimensions for the weight racks and fitness benches were also recorded. The reception employee remained seated for the duration of her shift, therefore anthropometric measurements were recorded in a seated posture. We also recorded the dimensions for the workstation, task chair, and the monitor/keyboard used by this employee, which were all measured from the floor.

2.2.5 Video Analysis

Video recordings for all three tasks were recorded and analyzed using the Simplified Ergonomics Checklist (Fernandez & Marley, 2013, p. 194) by three of the current authors independently and disagreements were resolved before proceeding. Both employees signed a video consent form. For the weight re-racking task, video feed was recorded while the employee picked up loose plate weights from the ground and placed them on the designated racks. The video analysis for this task focused on awkward postures, range of motion, and applied forces required. The second analysis focused on repetitive grip motions and awkward postures involved with cleaning the fitness equipment. The video analysis for the reception employee focused on extended reaches and problematic postures associated with improper task chair and workstation dimensions.

3. Results

3.1 BodyMap Assessment

The results from the BodyMap assessment for the reception employee identified four areas of discomfort including neck, eyes, right shoulder, and mid-to-lower back. All of these areas fell within the “green zone - not likely to seek treatment” (Fernandez & Marley, 2013, p. 190). The floor employee indicated more frequent and severe levels of discomfort than the reception employee. This employee indicated 12 areas of discomfort with scores in the “green zone - not likely to seek treatment, yellow zone - somewhat likely to seek treatment, and red zone - very likely to seek treatment.” This employee also reported frequent (few times/week to everyday) and very uncomfortable levels of discomfort (range: 2 - 8, M = 3.92), which could have been exacerbated by the required standing posture for the duration of his shift. This was especially important to consider because this employee was tasked with more physically demanding duties than the reception employee. Figure 1 illustrates the results for the severity of discomfort.

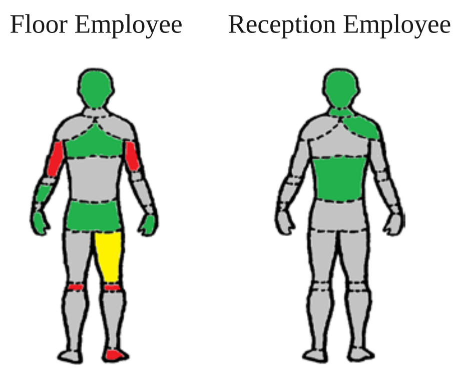

Figure 1. Visual comparison of BodyMap assessment results for the employee who maintained and cleaned the fitness equipment (left) and the employee who registered gym members (right). Gray = no discomfort; green = not likely to seek treatment; yellow = somewhat likely to seek treatment; red = very likely to seek treatment.

3.2 RULA

The RULA scores for the employee who performed the equipment cleaning task received a four for left upper extremities (further investigation is needed, and changes may be required) and a five for the right upper extremities (investigation and changes are required soon). Additionally, the RULA scores for the employee who registered gym members was two for left upper extremities (posture acceptable if not maintained or repeated for long periods) and five for the right upper extremities (investigation and changes are required soon).

3.3 NIOSH Lifting Index

Due to the variable nature of the weight re-racking task, best, medium, and worst case scenarios for height and weight were used to calculate the NIOSH Lifting Indices (Waters & Putz-Anderson, 1991). The employee who performed this task had NIOSH Lifting Indices ranging from 0.32 - 3.84 (M = 1.79; see Figure 1). It was assumed that this employee did not exhibit twisting of the back and that he did not carry the plates more than one or two steps. Additionally, it was assumed that the lifts were executed in a short duration with no more than three lifts per minute for four hours.

Table 1. NIOSH Lifting Indices for the Weight Re-racking Task.

	Light (2.5 lbs)	Medium (25 lbs)	Heavy (45 lbs)
Low (11”)	0.33	1.65	2.97
Medium (30”)	0.32	1.58	2.85
High (61”)	0.43	2.14	3.84

Note. Green = acceptable lifting; yellow = increased risk of injury and controls should be considered; red = requires redesign of the lifting task.

3.4 Office Ergonomics Evaluation

The anthropometric measurements for both employees are displayed in Tables 2 and 3. For the registration task, it was found that the task chair and layout of the workstation needed improvement. Specifically, the task chair did not have proper lumbar support, was non-adjustable, and had non-locking wheel casters (on carpet flooring). The armrests were angled at -10 degrees with a height of 24 inches in the front and 28 inches in the back. Additionally, the seat depth was 19 inches, and the width of the chair was tapered with the front width of the seat pan measuring 14 inches. According to the BIFMA G1-2002 Ergonomics Guideline (BIFMA, 2002), the dimensions that were not recommended for the task chair included the seat width ($\geq$ 18 inches), seat depth (< 16.9 inches), and armrest height (6.9-10.8 inches).

The mouse and keyboard were slightly raised and measured 31 inches from the floor. Although the monitor was in-line with the keyboard, the keyboard and monitor were positioned well below the ANSI/HFES (2007) suggested dimension of at least 3.9 inches. Additionally, a footrest was not provided, but was recommended since the employee's feet barely reached the ground.

Table 2. Anthropometric Measurements (inches) for Floor Employee.

Measure	Dimensions	Measure	Dimensions
Knee height	22”	Standing elbow height	44”
Elbow to elbow breadth	18”	Shoulder height	56”
Standing knuckle height	30”	Stature	68”

Table 3. Anthropometric Measurements (inches) for Reception Employee

Measure	Dimensions	Measure	Dimensions
Popliteal height	19”	Thigh height	22.5”
Seated elbow height	26.5”	Seated eye height	46”
Heel height	2”	Stature	64”
Elbow to elbow breadth	19.5”	Buttock to popliteal	21”

3.5 Video Data Analysis

The employee who performed the weight re-racking task exhibited body postures and ranges of motion that posed ergonomic risk factors (see Figure 2, left). When this employee bent down to pick up the plate weight, he displayed flexion of the hips, knees, neck, back (to an extreme angle), and often engaged in a twisting motion as well. Additionally, both upper arms were flexed when grasping a weight off the ground, and both elbows were extended and then flexed when he picked up the weight. The heaviest plates were designed with handles and therefore permitted good grip coupling. However, the plates ranged from 2.5 to 45 pounds and the grip force required ranged from low to high. The weight racks had several levels at varying heights and depending on which level the employee placed the weight, the plates were lifted from zero inches (floor) to 61 inches (highest rack).

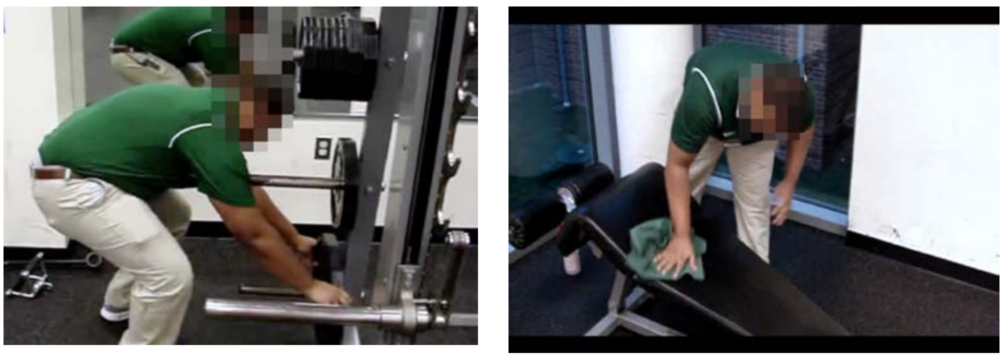

Figure 2. Floor Employee Re-racking Weights (left) and Cleaning Fitness Equipment (right).

While cleaning the equipment, the employee flexed and twisted his back to get closer to the bench, which was between four and 38 inches from the ground (see Figure 2, right). His lower body posture remained in a neutral posture during this process. The cleaning fluid was dispensed from a non-powered, pistol-grip bottle weighing approximately one pound. The spray function of the bottle required a medium-to-light amount of force to operate. Research using comparable spray bottles have found that the typical amount of force required to operate the trigger is five pounds, which falls within the upper-acceptable range of force required (Rice, Leonard, & Carter, 1998). In its entirety, the first step of the cleaning process takes approximately 10 seconds and 5-8 squeezes of the trigger per bench.

The second step of the cleaning process was more physically demanding. The employee thoroughly wiped every surface of each bench in the gym (approximately 25) including the benches for free-weights and the benches attached to the cable machines. While wiping, the employee exhibited postures that increase the risk of injury such as, flexion of the back and right shoulder, twisting of the back, extension of the right wrist, as well as slight ulnar and radial deviation of the right wrist (while wiping back and forth). This step takes approximately 30 seconds to complete. The total time to clean the fitness benches was approximately 20 minutes.

The results from the Simplified Ergonomics Checklist for the registration task showed that the employee exhibited noticeable back extension, right shoulder flexion (> 25 degrees), right elbow flexion and extension, right wrist extension (> 30 degrees), and right hand radial deviation. The posture of the right shoulder, hand, and wrist were identified as the most likely to increase the risk of injury. The employee also displayed static loading on the right upper arm with occasional reaches, which is consistent with the posture results. The employee exhibited right-handed pinch grip while registering gym members with a low level of force for an average of once per minute.

4. Discussion

The results from this case study identified several ergonomic risk factors for employees at George Mason University's Skyline Fitness Center. The floor employee was responsible for re-racking weights that were left on the gym floor. One concerning finding was that this employee lifted the weights from below the knees and to above the shoulders. Additionally, this employee engaged in problematic flexion and twisting of the back during each lift. As evidenced by the NIOSH Lifting Indices, changes to the nature of the task are required. For example, administrative changes such as training could emphasize the importance of lifting from the legs instead of the back. In addition, training protocol could explicitly instruct the employee to avoid twisting of the back and instead take an extra step to properly align oneself during the lift.

The floor employee was also responsible for cleaning the fitness equipment. For this task, the employee used a pistol-grip spray bottle to apply a cleaning solution to the equipment, and then used a towel to wipe down the equipment. The main risk factor exhibited in this task was the repetitive nature of cleaning all of the equipment in the facility. These repetitive motions included flexion and twisting of the back to reach the equipment, flexion of the shoulder during extended reaches, flexion and extension of the elbow while wiping the equipment, and flexion of the back to set down and pick up the spray bottle in between each clean. It was recommended that this employee be provided with a holster for the spray bottle to minimize flexion of the back. An administrative change was also recommended including training the employee to spray the cleaning solution onto the towel rather than onto the equipment, and to sidestep while cleaning instead of twisting the back to reach all areas of the equipment. These administrative and engineering changes would help to reduce several of the problematic postures and associated MSDs.

The employee who registered gym members displayed non-neutral postures in the upper extremities as evidenced in the video analysis. These postures included flexion of the right shoulder during extended reaches, flexion and extension of the right elbow, and extension and radial deviation of the right wrist. It was recommended that engineering changes be made to modify the existing workstation including purchasing a new chair, and repositioning the monitor, keyboard, and registration device. An optimal chair for this workstation and task would be adjustable, allowing each employee to individually modify the backrest height, armrests, and seat height to fit their anthropometric measurements. The current chair provided no lumbar support and had armrests that were too wide for the employee we evaluated. An adjustable chair would fix both of these issues and reduce the risk of injury. Additionally, it was suggested to position the keyboard so that the home row to the edge of the workstation measured at least 3.9 inches, and to reposition the registering device to be within the normal ROM zone (< 23.5” from elbow). This was the preferred recommendation as it is cost effective and would require minimal implementation changes.

Although there was only one reported injury within the previous 6 years at the Skyline Fitness Center, the safety of their employees was of the utmost importance to the management. As such, we recommended implementing the above ergonomic controls to continue to ensure employee safety. In addition to ensuring employee safety, the above recommendations will likely improve productivity, efficiency, and overall workplace satisfaction.

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