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ERGONOMIC EVALUATION OF DEPARTMENT-BASED MUSCULOSKELETAL SYSTEM RISKS IN AUTOMOTIVE AFTER-SALES SERVICES USING CMDQ AND QEC METHODS

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Keywords

Automotive after-sales services
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CMDQ
QEC

Abstract

This study evaluates the physical strain and ergonomic risks in authorized automotive service centers across four departments: mechanical, body repair, electrical, and service consultancy. Utilizing a cross-sectional design (n=17), the study combined the Quick Exposure Check (QEC) for objective risk assessment and the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) for subjective discomfort reporting. Inferential statistical analyses, including the Kruskal-Wallis test and Spearman correlation, were performed to evaluate departmental differences and methodological alignment. Within the study sample, mean risk levels appeared higher in the mechanical and body repair departments, although these differences were not statistically significant (p>0.05). Discomfort in the mechanical department was primarily concentrated in the lower back and neck, while shoulder and upper arm discomfort predominated in body repair. In the service consultancy department, moderate to high risks were identified in the neck and lower back due to workstation ergonomics. Correlation analysis revealed a very low and non-significant relationship between CMDQ and QEC scores (r=0.076, p>0.05), suggesting that perceived discomfort does not always align linearly with objective exposure levels. This study highlights the importance of a multi-method approach and provides practical, department-specific recommendations for improving ergonomic conditions in automotive after-sales services.

OTOMOTİV SATIŞ SONRASI HİZMETLERİNDE BÖLÜM BAZLI KAS-İSKELET SİSTEMİ RİSKLERİNİN CMDQ VE QEC YÖNTEMLERİ İLE ERGONOMİK DEĞERLENDİRİLMESİ

Anahtar Kelimeler

Otomotiv satış sonrası hizmetleri
Kas-iskelet sistemi rahatsızlıkları
Ergonomi
CMDQ
QEC

Öz

Bu çalışma, yetkili otomotiv servis merkezlerindeki fiziksel zorlanma ve ergonomik riskleri; mekanik, kaporta onarım, elektrik ve servis danışmanlığı olmak üzere dört departman bazında değerlendirmektedir. Kesitsel bir araştırma tasarımı (n=17) kullanılan çalışmada, nesnel risk değerlendirmesi için Hızlı Maruziyet Değerlendirmesi (QEC) ve öznel rahatsızlık bildirimi için Cornell Kas İskelet Sistemi Anketi (CMDQ) yöntemleri bir arada kullanılmıştır. Departmanlar arası farklılıkları ve yöntemlerin uyumunu değerlendirmek amacıyla Kruskal-Wallis testi ve Spearman korelasyon analizini içeren çıkarımsal istatistiksel analizler uygulanmıştır. Çalışma örneklemi genelinde, ortalama risk düzeylerinin mekanik ve kaporta onarım departmanlarında daha yüksek olduğu görülmüş; ancak bu farklılıklar istatistiksel olarak anlamlı bulunmamıştır (p>0.05). Mekanik departmanındaki rahatsızlıklar temel olarak bel ve boyun bölgelerinde yoğunlaşırken, kaporta onarım departmanında omuz ve üst kol rahatsızlıkları baskın çıkmıştır. Servis danışmanlığı departmanında, çalışma istasyonu ergonomisine bağlı olarak boyun ve bel bölgelerinde orta ile yüksek düzeyde riskler belirlenmiştir. Korelasyon analizi, CMDQ ve QEC puanları arasında çok düşük ve anlamsız bir ilişki ortaya koymuş olup (r=0.076, p>0.05), bu durum algılanan rahatsızlık düzeylerinin nesnel maruziyet seviyeleri ile her zaman doğrusal bir şekilde örtüşmediğini göstermektedir. Bu çalışma, çok yöntemli bir yaklaşımın önemini vurgulamakta ve otomotiv satış sonrası hizmetlerinde ergonomik koşulların iyileştirilmesi için departmana özel pratik öneriler sunmaktadır.

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1. Introduction

Ergonomics is an interdisciplinary field of science that aims to harmonize work, the working environment, and the equipment used with human physical, cognitive, and psychosocial characteristics (Dul and Weerdmeester, 2001; Babalık, 2018). At the core of the ergonomic approach lies the principle of adapting the work to the employee rather than requiring the employee to adapt to the work. This approach aims to protect employee health, reduce occupational accidents and diseases, and enhance overall productivity.

Musculoskeletal disorders (MSDs) are health problems affecting muscles, joints, tendons, ligaments, and spinal structures. These conditions are predominantly associated with repetitive movements, awkward postures, excessive force application, and prolonged static loading (Torp et al., 1996). Activities performed in the automotive maintenance and repair sector encompass many of these risk factors simultaneously, exposing employees to high levels of biomechanical strain.

After-sales services in the automotive sector consist of various activities involving significant physical and cognitive workloads, such as maintenance, repair, bodywork, electrical services, and service consultancy (Bengül, 2018; Özgüner and Kurtuldu, 2015). During these activities, employees are exposed to numerous ergonomic risk factors, including frequent repetitive movements, awkward working postures, heavy lifting, and prolonged standing or static positions. The literature emphasizes that such risk factors are primary determinants in the emergence of musculoskeletal disorders (MSDs) (Mahboobi et al., 2020; David et al., 2008; Torp et al., 1996).

Musculoskeletal disorders are among the most common occupational diseases in the automotive maintenance and repair sector, with high prevalence rates (50–70%) reported in the lower back, back, neck, and upper extremities (Hafez, 2022; Mahboobi et al., 2020). These disorders not only threaten employee health but also lead to significant economic costs for businesses due to labor loss, decreased productivity, and increased turnover rates (Gorasso et al., 2023; Sultan-Taieb et al., 2017; Bevan, 2015). Especially in automotive and similar workshops where manual maintenance and repair tasks are intensive, systematic assessment of ergonomic risks has become a critical necessity for occupational health and safety (Nwanya and Ukoha, 2025; Asadi et al., 2019; Nasaruddin et al., 2014).

An examination of ergonomics-based studies in automotive services reveals that most research focuses on production lines and manufacturing processes, while after-sales services and authorized service environments are addressed in relatively limited numbers (Aziz et al., 2017; Vandergrift et al., 2012). Furthermore, a significant portion of existing studies evaluates ergonomic risks using a single method, often failing to address subjective employee complaints alongside objective observation-based risks (Zaki et al., 2023; Fazi et al., 2019). However, the literature emphasizes the necessity of using subjective and objective methods together for an accurate assessment of musculoskeletal disorders (Fagarasanu and Kumar, 2006; Erdinc et al., 2011).

In this context, the combined use of the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) and the Quick Exposure Check (QEC) allows for the simultaneous evaluation of both employee-reported musculoskeletal complaints and the postural and physical risks encountered during tasks (David et al., 2008; Erdinc et al., 2011). While the CMDQ identifies the frequency, severity, and interference with work of discomfort across body regions (Hedge et al., 1999), the QEC method systematically analyzes ergonomic risk factors such as working postures, repetition, force, vibration, and work pace (Li and Buckle, 1998).

This study aims to identify and evaluate the musculoskeletal risks of personnel working in a private authorized service center within the scope of automotive after-sales services on a department-specific basis. Based on the findings, the study also aims to provide ergonomic improvement recommendations to mitigate these risks. Accordingly, the ergonomic risk profiles of employees in the electrical, body repair, mechanical, and office departments were evaluated using the CMDQ and QEC methods. The study is intended to contribute preliminary evidence on ergonomic risks in automotive service processes and to offer context-specific ergonomic intervention suggestions based on the evaluated service center. To this end, the study seeks to answer the following research questions:

1. Which tasks performed in automotive services lead to higher musculoskeletal risks?
2. What is the distribution of musculoskeletal disorders across body regions according to departments?
3. Are there observed differences between departments in terms of CMDQ and QEC scores?
4. What ergonomic improvement recommendations can be developed to reduce the identified risks?

2. Methodology

2.1. Study Setting and Participants

This study was designed as a cross-sectional and observational field study aimed at identifying musculoskeletal disorders and ergonomic risks among personnel employed at an authorized automotive after-sales service center. To evaluate ergonomic risks through both employee self-reports and direct observation, the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) and the Quick Exposure Check (QEC) were used in combination.

The research was conducted at a private authorized service center in Samsun, Turkey, providing after-sales maintenance and repair services. The facility comprises four main departments: mechanical maintenance and repair, body repair, electrical, and service consultancy (office processes). Work environments include vehicle lifts, hand tools, electrical equipment, workbenches, and office workstations; prevailing working conditions were taken into account throughout the evaluation process.

Inclusion criteria required participants to have been working in their respective departments for at least six months and to be actively performing their duties during the evaluation period. The study was conducted on a voluntary basis. Prior to data collection, the purpose of the study was explained to all participants, and demographic and occupational information—including age, height, weight, educational background, and industry and firm experience—was recorded. The study population consisted of 17 active employees: 2 in the electrical department, 4 in body repair, 7 in the mechanical department, and 4 in the service consultancy (office) department.

Ethical approval was obtained from the Ondokuz Mayıs University Social and Human Sciences Research Ethics Committee (Decision Date: 27.02.2026; Meeting No: 2; Decision No: 2026-216). The study was approved unanimously.

The field study and data collection processes were carried out during March 2026 at the designated service center, following the receipt of ethical approval.

2.2. Study Design and Work Processes

Automotive service environments are complex work systems in which distinct ergonomic risk profiles emerge across different departments. In the mechanical and body repair departments, employees are generally exposed to physical risks such as bending, reaching, crouching, lifting heavy components, and sustaining awkward postures for extended periods. In the electrical department, working in confined spaces, performing overhead tasks, and executing repetitive hand-wrist movements are the predominant risk factors. For employees in service consultancy and office processes, prolonged sitting, prolonged screen use, and static neck and lower back postures constitute the primary ergonomic concerns.

Within the scope of the ergonomic risk assessment, the core work processes routinely performed by employees in each department were analyzed separately. For each process, the working postures adopted, repetitive movements performed, forces applied, and static loads sustained by employees were taken into consideration:

- *Service Consultancy (Office Processes)*: Customer reception, computer use, paperwork, and telephone calls.
- *Electrical Department*: Maintenance resets, dashboard assembly and disassembly, and electrical equipment inspections.
- *Mechanical Department*: Periodic maintenance, detailed servicing, and under-vehicle and over-vehicle maintenance and repair operations.
- *Body Repair Department*: Dent removal, damage repair, polishing, and painting operations.

2.3. Methods Used

The CMDQ was employed to assess the frequency, severity, and work interference level of musculoskeletal discomfort experienced by employees in various body regions over the preceding week. The questionnaire encompasses 18 distinct body regions (Erdinc et al., 2011). The total discomfort score for each body region was calculated by multiplying the frequency, severity, and work interference scores. The Turkish-validated version of the CMDQ was preferred to capture the subjective discomfort levels of the employees.

The QEC method was applied to evaluate ergonomic risk factors encountered during work tasks. The method accounts for posture, repetition, force, vibration, work pace, and stress factors across the back, neck, shoulder/arm, and hand-wrist regions (David et al., 2008). QEC assessments were conducted based on both direct observations by the researcher and feedback provided by the employees. For each task, 4–6 observations were performed, and the resulting scores were analyzed using QEC evaluation tables. Total QEC scores were classified as low, moderate, high, or very high according to ergonomic risk levels. Risk levels were interpreted in accordance with the classification proposed by David et al. (2008), which also served as the basis for determining ergonomic intervention requirements.

2.4. Data Collection and Analysis

Data collection was carried out during working hours in March 2026 without disrupting the workflow. CMDQ questionnaires were first

completed by the participants, followed by on-site QEC assessments conducted during the relevant tasks. Observations were selected to represent the most physically demanding and frequently repeated working postures. CMDQ results were analyzed by body region and department to reveal the distribution of musculoskeletal discomfort. QEC scores were compared on a task and department basis.

Findings were presented using descriptive statistics, and ergonomic risk levels were interpreted accordingly. In addition to descriptive statistics, inferential analyses were performed to evaluate the findings more rigorously. Due to the small sample size (n=17) and the non-parametric nature of the data, the Kruskal-Wallis test was employed to cross-departmentally compare CMDQ discomfort scores and QEC risk levels. Furthermore, the Spearman correlation coefficient was calculated to evaluate the relationship between subjective discomfort reports and objective ergonomic exposure scores. The significance level for all statistical tests was set at $p<0.05$. By evaluating the CMDQ and QEC results in combination through these descriptive and inferential methods, department-based ergonomic risk profiles were established.

3. Results and Discussion

3.1. Findings on the Demographic and Occupational Characteristics of the Study Sample

A total of 17 employees working in the electrical, body repair, mechanical, and service consultancy departments of an automotive maintenance and repair company were included in this study. All participants were actively performing their routine duties that involved physical workload during the data collection period. Descriptive statistics regarding the participants' demographic and occupational characteristics are presented in Table 1.

Table 1. Age, Height, Weight, and Experience Characteristics of the Participants

Variable	Mean	Min–Max
Age (years)	32	22 – 50
Height (cm)	177.94	165 – 188
Weight (kg)	84.71	75 – 90
Industry experience (years)	7.59	1 – 15
Company tenure (years)	4.56	0.50 – 12

The mean age of the participants was 32 years, with an average industry experience of 7.59 years and a mean company tenure of 4.56 years. Examination of the descriptive statistics reveals a heterogeneous structure, including both young employees and personnel with many years of professional experience. The fact that industry experience is higher than company tenure indicates that the employees had previously held similar positions in the automotive sector. The distribution of the study sample by sex, educational status, and department is presented in Table 2.

Table 2: Information on Participants' Sex, Educational Status, and Department Distribution

Variable	n	%	Variable	n	%
Gender			**Department**		
Male	16	94	Electrical	2	12
Female	1	6	Body Repair	4	24
Educational Status			Mechanical	7	41
Middle School	9	53	Service Consultancy	4	24
High School	1	6			
University	7	41			

The distribution of participants by sex, education level, and department describes the profile of the employees included in this specific service center. It should not be interpreted as representative of the broader automotive maintenance and repair sector. The high proportion of employees in the mechanical and body repair departments indicates that the study focuses on work processes where ergonomic risks are most intense.

3.2. Findings on Body Mass Index (BMI) Distribution

The Body Mass Index (BMI) values of the participants were calculated using measured height and weight data and evaluated according to the World Health Organization (WHO) classification. Accordingly, participants were classified as underweight (<18.5 kg/m^2), normal (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30.0 kg/m^2) (WHO, 2016). The BMI distribution of the participants is shown in Table 3.

Table 3. BMI Distribution of Participants According to WHO Classification

BMI Class (kg/m^2)	n	%
Underweight (<18.5)	0	0
Normal (18.5–24.9)	2	12
Overweight (25.0–29.9)	15	88
Obese (≥30.0)	0	0
Total	**17**	**100**

The BMI distribution shows that a significant portion of the employees falls into the overweight category. This is considered a risk factor that may increase the biomechanical loads on the musculoskeletal system,

especially in automotive maintenance and repair work where physical exertion is intense. In the literature, high BMI values are reported to be associated with increased loads on the spine, decreased postural stability, and prolonged static muscle activity (Seaman, 2013; Yoo et al., 2014; Chen et al., 2023). In this context, the BMI distribution in the study should be evaluated as an individual risk factor that may lead to the emergence of musculoskeletal disorders.

3.3. Findings from the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ)

The CMDQ is a reliable subjective data collection tool that evaluates musculoskeletal discomfort experienced over the past week by body region in terms of frequency, severity, and interference with work (Erdinc et al., 2011; Hedge et al., 1999). The CMDQ results indicate that musculoskeletal discomfort among personnel working in automotive after-sales services is concentrated in specific body regions. The distribution of total CMDQ discomfort scores by body region is presented in Table 4 (Research Question 2). When complaint rates and mean discomfort values per complaint were examined by body region, the highest complaint rates were observed in the low back (64.7%), neck (53%), and back (53%). These were followed by the wrist (right: 35.3%) and knee (17.6%). Regarding mean values per complaint, the highest scores were recorded for the low back (9.27) and back (6.67).

Within the present study sample, musculoskeletal discomfort was predominantly reported in spinal regions, a pattern that is broadly consistent with findings reported in the literature for automotive technicians. Mahboobi et al. (2020) and Hafez (2022) reported that the low back, back, and neck are the most frequently affected body regions among automotive technicians. Similarly, Torp et al. (1996) emphasized that static and dynamic loads on the low back in particular constitute a high risk among automotive mechanics.

In the electrical department, CMDQ scores were relatively low; however, notable discomfort was observed in the neck, upper arm, and wrist regions. This can be explained by working in confined spaces, maintaining the head and neck in a fixed position for extended periods, and the intensity of fine hand–wrist movements. The literature indicates that neck and upper-extremity complaints are common in tasks involving precise assembly and electrical operations (David et al., 2008). The findings of this study support this observation.

In the body repair department, CMDQ scores were higher compared to other departments, and discomfort was notably distributed across the neck, back, low back, upper extremities, and lower extremities. In particular, employees with total CMDQ scores of 38 and 25 reported simultaneous discomfort in multiple body regions. This is associated with the intensity of demanding postures during dent repair, sanding, polishing/compounding, and painting tasks, including repetitive arm movements, bending, squatting, and prolonged standing. Hafez (2022) reported that the shoulder, low back, and knee regions are at high risk in body repair and vehicle body work, and the findings of this study are strongly consistent with the literature.

Mechanical department employees constituted the group with the highest total CMDQ scores in the study. In particular, some employees reported scores as high as 27 for the low back region. The co-occurrence of low back, back, neck, and lower-extremity complaints in the mechanical department reflects the intensity of bending, reaching, kneeling, and static loading during under-vehicle and over-vehicle maintenance and repair tasks. Torp et al. (1996) and Mahboobi et al. (2020) highlighted the low back and back as the most critical risk areas in mechanical maintenance work and emphasized the priority of ergonomic interventions in such tasks. In the present sample, the mechanical department exhibited the highest observed CMDQ scores and may represent a priority area for ergonomic assessment and intervention.

Although CMDQ scores in the service consultancy department were lower than those in the workshop departments, discomfort was reported in the neck, back, and low back regions. This is associated with prolonged sitting, extended screen-based work, and sustained static neck–lumbar postures. The literature notes that neck and low-back pain are common among office workers and that such complaints are generally low in intensity but persistent (David et al., 2008). The findings of this study indicate that, although service consultancy tasks are less physically demanding, ergonomic risks are not fully eliminated.

When the CMDQ results are evaluated within this study sample, the pattern of reported musculoskeletal discomfort appears to vary according to job type and department-specific task characteristics. While the mechanical and body repair departments are characterized by more widespread and severe complaints due to high physical workload, the electrical and service consultancy departments exhibit more limited but region-specific risks.

Table 4. Distribution of Department-Based CMDQ Discomfort Scores

Dept.	CMDQ Score	Neck	Shoulder (R)	Shoulder (L)	Back	Upper Arm (R)	Upper Arm (L)	Low Back	Forearm (R)	Forearm (L)	Wrist (R)	Wrist (L)	Hip	Thigh (R)	Thigh (L)	Knee (R)	Knee (L)	Lower Leg (R)	Lower Leg (L)	Foot (R)	Foot (L)
Electrical	18	8						8			1	1									
	7	2				4					1										
Body Repair	38	6									8		8	8	8						
	10	1			8			1													
	16							4				4				4	4				
	25	4			12			8			1										
Mechanical	27							27													
	31							27			4										
	19				2	2	2	3	1	1				1	1	1	1	1	1	1	1
	3							4									2				
	16		2	2	8			4													
	23	1		1	8							1	4								
	13	1			4			8													
Service Consultancy	11		2			1		8													
	2				2																
	9	1			8																
	13	1			8				1		1				2						
Complaint Rate (%)		52.94	11.76	11.76	52.94	17.65	5.88	64.71	11.76	5.88	35.29	17.65	11.76	11.76	17.65	11.76	17.65	5.88	5.88	5.88	5.88
Mean value per complaint		2.78	2.00	1.50	6.67	2.33	2.00	9.27	1.00	1.00	2.67	2.00	6.00	4.50	3.67	2.50	2.33	1.00	1.00	1.00	1.00

These findings are consistent with the view in the literature that a uniform ergonomic risk approach may be insufficient and suggest the potential value of department-based ergonomic risk assessments and targeted interventions. When the CMDQ data are evaluated together with the QEC results presented in the subsequent section, the relationship between subjective discomfort reports and objective ergonomic exposures can be understood more clearly.

3.4. Findings from the Quick Exposure Check (QEC)

The QEC method was used in this study to evaluate ergonomic exposures. QEC assessments were conducted at the individual level during each employee's routine job tasks, and department-based mean QEC values were calculated from the resulting scores. Individual QEC scores by department, department-based means, high-risk body regions, and ergonomic risk levels are presented in Table 5 (Research Question 1).

Table 5. Distribution of Department-Based QEC Scores

Department	Main Tasks Assessed	Employee	QEC Score	Dept. Mean QEC Score	High-Risk Body Regions	QEC Risk Level
Mechanical	Periodic maintenance, under-/over-vehicle repair	1	66.47	76.18	Low back, back, neck	High–Very High
		2	67.04			
		3	92.04			
		4	90.34			
		5	90.12			
		6	65.90			
		7	61.36			
Body Repair	Dent repair, sanding, polishing/compounding	1	81.48	80.99	Shoulder, upper arm, low back	Very High
		2	84.56			
		3	79.54			
		4	78.40			
Electrical	Dashboard operations, electrical inspections	1	37.03	43.51	Neck, wrist	Low–Moderate
		2	50.00			
Service Consultancy	Computer use, customer intake	1	73.29	64.28	Neck, low back	Moderate–High
		2	75.92			
		3	48.14			
		4	59.65			

The combined application of CMDQ and QEC enabled simultaneous assessment of perceived discomfort and objective ergonomic exposure, addressing Research Question 3. When findings from both instruments were examined at the individual and department levels, a descriptive consistent pattern emerged: departments with higher QEC scores tended to report greater musculoskeletal discomfort in the corresponding body regions on the CMDQ.

In the mechanical and body repair departments, elevated QEC scores converged with CMDQ complaints concentrated in the low back, back, neck, and upper extremities, suggesting that heavy physical workload, awkward postures, and repetitive movements may contribute to musculoskeletal discomfort in these departments. The narrow inter-individual QEC range in the body repair department, combined with CMDQ complaints concentrated in the shoulder and upper arm, points to upper-extremity-dominant ergonomic loading as a defining characteristic of body repair work. These findings are consistent with Torp et al. (1996) and Mahboobi et al. (2020), who identified the low back and back as critical risk regions in mechanical maintenance, and with Hafez (2022), who linked shoulder and upper-arm complaints specifically to sanding and polishing tasks in automotive technicians.

In the electrical department, the discordance between comparatively low QEC scores and reported neck and wrist discomfort on the CMDQ illustrates that ergonomic risk is not solely a function of physical load magnitude. As David et al. (2008) note, the QEC method captures static posture-related risks that may generate musculoskeletal strain even at moderate exposure levels; Fagarasanu and Kumar (2006) similarly report that neck and upper-extremity complaints are prevalent in repetitive, precision-based tasks. The present findings are consistent with both observations; however, they should be interpreted cautiously given the limited sample size, particularly in the electrical department.

In the service consultancy department, the variability in individual QEC scores—interpreted alongside CMDQ results—suggests that ergonomic exposure is substantially mediated by individual behavioral factors. Despite lower overall exposure relative to workshop departments, the presence of neck and low back complaints aligns with evidence that prolonged sedentary work and sustained screen use independently contribute to musculoskeletal discomfort in these regions (Ekin et al., 2021; Kahya and Özkan, 2017).

The use of a single assessment method is widely regarded as insufficient for comprehensive ergonomic risk characterization; observational tools are therefore commonly combined with self-report instruments (Fagarasanu & Kumar, 2006). Studies employing QEC alongside REBA, RULA, and CMDQ confirm that such combinations yield more complete risk profiles (Mazloumi et al., 2025; Eyvazlou et al., 2021; Khan and Deb, 2019). The dual-method approach adopted in this study enabled both objective exposure quantification and characterization of perceived discomfort. While the statistical correlation between these measures was weak, the combined data provides a more comprehensive, albeit complex, basis for ergonomic decision-making.

From a practical standpoint, the findings suggest that department-specific approaches to ergonomic risk management may be beneficial in the evaluated authorized automotive service center and should be explored in similar settings. Physical ergonomics interventions—including postural correction, mechanical aids, and task rotation—should be prioritized in the mechanical and body repair departments, while workstation redesign and behavioral modifications targeting static postures are more critical in the electrical and service consultancy departments. These results reinforce observations that ergonomic risks specific to automotive after-sales service processes have received limited attention in the literature and strengthen the applied contribution of the present study.

3.5. Statistical Analysis of Departmental Differences and Correlations

To evaluate the statistical significance of the findings, non-parametric tests were employed due to the small sample size and non-normal distribution of the data. The Kruskal-Wallis test was used to determine whether CMDQ discomfort scores and QEC exposure levels differed significantly across the four departments. The results indicated no statistically significant difference between departments for CMDQ scores (p=0.1703). For QEC scores, the result approached the threshold of significance (p=0.0543). Although this does not meet the conventional p<0.05 criterion, the near-significant value suggests a marginal difference in physical exposure levels between departments, which may reach statistical significance in studies with larger sample sizes. From a clinical and practical perspective, the higher mean QEC scores in the mechanical (76.18) and body repair (80.99) departments compared to the electrical (43.51) and service consultancy (64.28) departments underscore the varying degrees of ergonomic risk inherent in different automotive service consultancy tasks.

Additionally, the relationship between subjective discomfort (CMDQ) and objective ergonomic exposure (QEC) was analyzed using the Spearman correlation coefficient. The analysis revealed a very weak and statistically non-significant correlation between the two measures (r=0.0761, p=0.7717). This lack of correlation suggests that perceived musculoskeletal discomfort among the participants is not solely determined by the magnitude of instantaneous physical exposure captured by the QEC. This discordance is consistent with the literature, which suggests that individual pain thresholds, psychosocial factors, and the cumulative nature of musculoskeletal strain—rather than just peak exposure—influence subjective reports (David et al., 2008). These statistical findings reinforce the necessity of using multi-method approaches to capture the complex nature of ergonomic risks in the automotive after-sales sector.

4. Conclusion and Recommendations

This study employed a dual-method approach, integrating the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) and the Quick Exposure Check (QEC) to provide a comprehensive assessment of musculoskeletal risks in automotive after-sales services. While the CMDQ captured the subjective dimension of MSDs—quantifying the frequency, severity, and work interference of perceived discomfort—the QEC provided an objective, observational analysis of physical risk factors, including awkward postures, repetitive movements, forceful exertions, and work pace. The combined use of these two validated instruments enabled a complementary assessment of self-reported discomfort and observed occupational exposures within the study sample. By moving beyond isolated postural or symptomatic assessments, this study offers a holistic, department-based evaluation of ergonomic risks in the complex automotive service environment.

Based on the integrated findings of the CMDQ and QEC, targeted ergonomic intervention strategies have been developed to mitigate MSD risks across different service departments, addressing Research Question 4:

Mechanical Department: Given the high risk identified in the low back, back, and neck regions, interventions should prioritize engineering controls. The implementation of adjustable lifts and versatile work platforms is essential to minimize sustained trunk flexion and awkward overhead postures during under- and over-vehicle maintenance. The use of mechanical assist devices—such as pneumatic tools, specialized jacks, and lifting apparatus—should be expanded to reduce the compressive loading on the lumbar spine. Furthermore, administrative controls, including task rotation and the provision of adequate recovery periods between physically intensive assignments, are recommended to prevent cumulative fatigue. Ergonomics-based awareness training focusing on neutral spine maintenance and safe lifting techniques can further empower technicians to adopt protective work habits.

Body Repair Department: High exposure levels in the shoulder, upper arm, and low back necessitate the adoption of ergonomically designed, low-vibration power tools for sanding, polishing, and buffing tasks to reduce upper-extremity strain. Adjustable-height workstations and supportive jigs should be utilized for tasks requiring prolonged reaching or overhead work. To address the high frequency of repetitive arm movements, structured micro-breaks and increased task variety are critical. Additionally, for tasks involving prolonged standing, the provision of anti-fatigue matting and footwear with appropriate arch support is recommended to mitigate lower-extremity and lumbar discomfort.

Electrical Department: Ergonomic risks in this department are primarily localized to the neck and wrist. To reduce cervical flexion during intricate dashboard operations and precision assembly, workstations should be configured to support adjustable viewing angles, complemented by high-intensity task lighting. The use of ergonomic hand tools that promote neutral wrist alignment is essential for reducing localized musculoskeletal strain. Administrative measures, such as frequent short breaks and task diversification, can effectively mitigate the risks associated with sustained static postures.

Service Consultancy Department: Although exposure levels were moderate, the prevalence of neck and low back discomfort highlights the need for standardized office ergonomics. Interventions should focus on the provision of fully adjustable ergonomic seating, monitor stands to ensure eye-level screen alignment, and peripheral placement (keyboard/mouse) that supports neutral upper-limb posture. Encouraging regular movement intervals and increasing ergonomic literacy among staff can significantly reduce the adverse effects of prolonged sedentary work.

For sustainable risk reduction across all departments, periodic ergonomic assessments should be integrated into the organizational safety management system. The regular application of tools like the CMDQ and QEC will enable management to monitor the efficacy of ergonomic interventions and proactively address emerging MSD trends.

The holistic approach adopted in this study offers an exploratory contribution to the limited literature on department-based ergonomic assessments in automotive after-sales services by considering both workshop and office-based roles. While the CMDQ is subject to individual perception and recall bias, and the QEC is influenced by observer experience, their concurrent use effectively triangulates the data, enhancing the reliability of the findings.

However, this study is characterized by several limitations. First, the cross-sectional design limits the ability to establish long-term causal relationships. Second, the sample size is relatively small (n=17) and the distribution across departments is uneven, with only two participants in the Electrical department. This limited sample size reduces the statistical power and the generalizability of the findings to the broader automotive after-sales service sector; therefore, the results—particularly those regarding the Electrical department—should be interpreted with caution. Future research should employ longitudinal frameworks and include larger, multi-center, and more balanced samples to validate these findings and allow for more robust statistical comparisons. Furthermore, the integration of objective biomechanical measurements, such as wearable sensors or electromyography (EMG), could provide a more granular understanding of ergonomic strain in automotive service environments. In conclusion, this case-based study provides preliminary, context-specific evidence that may inform targeted, department-specific ergonomic improvements in the evaluated service center while enhancing both employee well-being and operational efficiency.

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Conflict of Interest

No conflict of interest was declared by the authors.

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