

Association Between Unilateral Water Container Carrying and Neck and Shoulder Asymmetry in Adolescents: A Cross-Sectional Study

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Abstract

Introduction: Repetitive unilateral water container carrying during adolescence may induce asymmetric mechanical loading and alter postural alignment because the musculoskeletal system is still developing.

Objective: This study investigated the association between unilateral water container carrying and the risk of neck and shoulder asymmetry among adolescents at SMA Negeri 1 Ndosu.

Methods: A cross-sectional study was conducted among 30 adolescents aged 15–20 years selected through purposive sampling. Unilateral loading was assessed using the Quick Exposure Check (QEC), whereas neck and shoulder asymmetry were evaluated using the AI Posture Evaluation and Correction System (APECS). Data were analyzed using Pearson correlation after the assumptions of normality and linearity had been satisfied, with statistical significance set at $p < 0.05$.

Results: Significant positive correlations were observed between unilateral loading and postural asymmetry. Shoulder/arm loading was associated with neck asymmetry ($r = 0.544$, $p = 0.002$) and shoulder asymmetry ($r = 0.757$, $p = 0.003$). Wrist loading showed the strongest association with shoulder asymmetry ($r = 0.804$, $p = 0.003$), whereas neck loading was significantly associated with neck asymmetry ($r = 0.501$, $p = 0.005$) and shoulder asymmetry ($r = 0.760$, $p = 0.004$).

Conclusion: Higher levels of unilateral water container carrying were significantly associated with greater neck and shoulder asymmetry among adolescents. These findings emphasize the importance of ergonomic interventions and preventive strategies to minimize musculoskeletal risks associated with repetitive unilateral load carrying.

Keywords

Adolescent; Ergonomics; Neck; Posture; Shoulder.

Introduction

Access to clean water is a fundamental requirement for maintaining health, sanitation, and quality of life. However, access to safe water remains limited in many rural areas of Indonesia, particularly in regions characterized by mountainous terrain and long distances between residential settlements and water sources. Consequently, community members frequently transport water manually using buckets or water containers to meet their daily household needs, including cooking, bathing, washing, and other sanitation-related activities. In many rural communities, this responsibility is shared not only by adults but also by children and adolescents as part of their routine household activities.

Water containers are commonly carried on one side of the body because this method is considered more practical when traversing narrow, steep, or uneven pathways.¹ Nevertheless, repetitive unilateral load carriage may impose asymmetric mechanical stress on the musculoskeletal system. Carrying a load on one side shifts the body's center of gravity, requiring continuous postural compensation to maintain balance during locomotion. These compensatory mechanisms involve increased muscle activation on one side of the body, head inclination, shoulder elevation, and alterations in spinal alignment. When sustained over prolonged periods, these biomechanical adaptations may lead to persistent postural asymmetry and increase the risk of musculoskeletal disorders.²

The potential consequences of unilateral loading are particularly important during adolescence because this developmental period is characterized by rapid musculoskeletal growth and maturation. During the adolescent growth spurt, skeletal development often progresses more rapidly than muscular adaptation, rendering postural control more susceptible to repetitive asymmetric mechanical loading.³ Continuous exposure to unilateral loading during this critical stage may interfere with normal postural adaptation, thereby increasing the likelihood of neck and shoulder asymmetry. Furthermore, prolonged postural asymmetry may alter mechanical load distribution across the musculoskeletal system, increase muscle tension, and contribute to future musculoskeletal complaints.^{4,5}

Previous studies have consistently demonstrated that unilateral load carriage influences postural balance and body alignment. Carrying loads on one side of the body has been shown to increase postural asymmetry through altered load distribution and compensatory biomechanical responses.² Non-ergonomic load carriage also increases mechanical stress on the musculoskeletal system, thereby elevating the risk of postural abnormalities and musculoskeletal disorders.⁶ Furthermore, repetitive load carriage has been reported to modify body mechanics during functional activities and adversely affect postural alignment.⁷ These findings collectively indicate that habitual unilateral loading may have substantial implications for musculoskeletal health, particularly among adolescents who are still undergoing physical development.

Despite these findings, previous investigations have primarily focused on unilateral loading associated with school backpacks, occupational tasks, or industrial activities. Evidence regarding habitual unilateral water container carrying as a routine household activity in rural communities remains scarce. Moreover, studies simultaneously evaluating ergonomic loading using the Quick Exposure Check (QEC) and postural asymmetry using the AI Posture Evaluation and Correction System (APECS) are still limited. Consequently, the relationship between unilateral water container carrying and objectively measured neck and shoulder asymmetry has not been adequately explored. This study addresses that knowledge gap by combining QEC to quantify ergonomic loading exposure and APECS to objectively evaluate postural asymmetry among rural adolescents.

Therefore, this study aimed to investigate the association between unilateral water container carrying and the risk of neck and shoulder asymmetry among adolescents at SMA Negeri 1 Ndosso. The findings are expected to provide scientific evidence regarding the biomechanical consequences of repetitive unilateral loading and to support the development of ergonomic education and preventive physiotherapy strategies aimed at reducing musculoskeletal disorders among adolescents living in rural communities.

Methods

This quantitative study employed a cross-sectional design to investigate the association between unilateral water container carrying and the risk of neck and shoulder asymmetry among adolescents at SMA Negeri 1 Ndosso, West Manggarai Regency, East Nusa Tenggara, Indonesia. The study population consisted of 42 students who met the predefined eligibility criteria. The minimum sample size was determined using the Slovin formula with a 10% margin of error, resulting in a required sample of 30 participants. Participants were subsequently recruited through purposive sampling according to predetermined inclusion and exclusion criteria. Eligible participants were adolescents aged 15–20 years who were actively enrolled at SMA Negeri 1 Ndosso, routinely carried water containers unilaterally during their daily activities, and voluntarily agreed to participate by providing written informed consent. Participants were excluded if they had a history of neck, shoulder, or spinal fracture or injury, musculoskeletal or neurological disorders affecting posture, or incomplete study data.

The independent variable was the level of unilateral loading during water container carrying, whereas the dependent variables were the risks of neck and shoulder asymmetry. Potential confounding factors, including body mass index, water container weight, carrying duration and frequency, hand dominance, and physical activity level, were not statistically controlled because the primary objective of this study was to evaluate the bivariate association between unilateral loading and postural asymmetry. Therefore, these variables were considered during the interpretation of the findings and acknowledged as study limitations.

Unilateral loading exposure was assessed using the Quick Exposure Check (QEC), an ergonomic assessment method developed to evaluate musculoskeletal risk exposure involving the back, shoulder and arm, wrist, and neck. In addition to working posture, the QEC evaluates movement frequency, task duration, external force, and psychosocial workload. Previous studies have demonstrated excellent psychometric properties of the instrument, including a Scale Content Validity Index exceeding 0.90, inter-rater reliability with intraclass correlation coefficients ranging from 0.71 to 0.97, test–retest reliability with kappa values ranging from 0.68 to 1.00, and weighted kappa values between 0.61 and 0.85, supporting its validity and reliability for ergonomic assessment. Neck and shoulder asymmetry were evaluated using the AI Posture Evaluation and Correction System (APECS) based on standardized digital photogrammetry. Previous validation studies have reported excellent inter-rater and intra-rater reliability for digital photogrammetric assessment, with reliability coefficients generally exceeding 0.80, supporting its application for quantitative postural evaluation. Supporting equipment included a smartphone, tripod, anthropometric instruments, and standardized observation forms.

Photographs were obtained using a smartphone mounted on a tripod positioned approximately 1.5 m from each participant, with the camera aligned at shoulder height to minimize perspective distortion. Anatomical landmarks were identified using skin markers before image acquisition. All photographs were captured under standardized lighting conditions while participants maintained a neutral standing posture. Anterior and posterior images were subsequently analyzed using the APECS application to quantify neck and shoulder asymmetry. Body height and weight were also measured using standard anthropometric procedures before postural assessment.

Data were analyzed using IBM SPSS Statistics. Descriptive statistics were used to summarize participant characteristics. Data normality was evaluated using the Shapiro–Wilk test, whereas linearity was examined through visual inspection of scatterplots between the QEC and APECS variables. Because all variables demonstrated normal distributions and linear relationships, Pearson correlation analysis was performed to examine the associations between unilateral loading and neck and shoulder asymmetry. Correlation coefficients (r), corresponding p values, and 95% confidence intervals calculated using Fisher's z transformation were reported. Statistical significance was established at $p < 0.05$. Multivariable analysis was not performed because the study was specifically designed to investigate bivariate associations, and potential confounding variables were neither measured comprehensively nor controlled within the study design.

The study was approved by the Research Ethics Committee of Universitas Dhyana Pura, Indonesia (Approval No. 001297/KEP Universitas Dhyana Pura/2026). Ethical approval was granted on 10 March 2026 and remained valid until 10 March 2027. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, and written informed consent was obtained from all participants before data collection commenced.

Results

A total of 30 adolescents who fulfilled the eligibility criteria completed this study. No participants were excluded after enrollment, and no missing data were identified during data collection. Participant characteristics, unilateral loading exposure, postural asymmetry, assumption testing, and correlation analyses are presented in Tables 1–8. The demographic characteristics of the participants are summarized in Tables 1 and 2.

Table 1. Distribution of Participants by Sex

Sex	n	%
Male	12	40.0
Female	18	60.0
Total	30	100.0

Table 2. Distribution of Participants by Age

Age (years)	n	%
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15	2	6.7
16	10	33.3
17	8	26.7
18	8	26.7
19	1	3.3
20	1	3.3
Total	30	100.0

As presented in Tables 1 and 2, female participants constituted the majority of the study population (60.0%), whereas males accounted for 40.0%. Participants ranged in age from 15 to 20 years, with those aged 16 years representing the largest proportion (33.3%), followed by participants aged 17 and 18 years (26.7% each).

The distribution of unilateral loading exposure and postural asymmetry is presented in Tables 3–5.

Table 3. Distribution of Unilateral Loading Based on the Quick Exposure Check (QEC)

Category	n	%
Moderate	14	46.7
High	16	53.3
Total	30	100.0

Table 4. Distribution of Shoulder Asymmetry Based on the AI Posture Evaluation and Correction System (APECS)

Category	n	%
Normal	3	10.0
High	27	90.0
Total	30	100.0

Table 5. Distribution of Neck Asymmetry Based on the AI Posture Evaluation and Correction System (APECS)

Category	n	%
Mild asymmetry	1	3.3
Moderate asymmetry	15	50.0
Severe asymmetry	14	46.7
Total	30	100.0

More than half of the participants (53.3%) were classified as having a high level of unilateral loading. Shoulder asymmetry was highly prevalent, with 90.0% of participants categorized as having a high risk of asymmetry. Moderate neck asymmetry was the most common finding (50.0%), followed by severe asymmetry (46.7%), whereas only one participant (3.3%) demonstrated mild neck asymmetry.

Before hypothesis testing, the assumptions of normality and linearity were evaluated to determine the suitability of parametric statistical analysis. The results of these assessments are presented in Tables 6 and 7.

Table 6. Shapiro–Wilk Normality Test Results

Variable	Statistic	n	p value
QEC Shoulder/Arm	0.731	30	0.098
QEC Wrist	0.712	30	0.087
QEC Neck	0.637	30	0.102
APECS Shoulder Asymmetry	0.947	30	0.142
APECS Neck Asymmetry	0.949	30	0.164

The Shapiro–Wilk test indicated that all variables were normally distributed ($p > 0.05$), confirming that the assumption of normality required for Pearson correlation analysis was satisfied.

Table 7. Linearity Assessment Between QEC and APECS Variables

Variable Relationship	Regression Equation	R ²	Interpretation
QEC Shoulder–APECS Shoulder	$y = -4.07 + 0.35x$	0.573	Positive linear
QEC Shoulder–APECS Neck	$y = 5.95 + 0.29x$	0.296	Positive linear
QEC Wrist–APECS Shoulder	$y = -7.00 + 0.40x$	0.646	Positive linear
QEC Wrist–APECS Neck	$y = 4.40 + 0.30x$	0.285	Positive linear
QEC Neck–APECS Shoulder	$y = -4.69 + 0.97x$	0.578	Positive linear
QEC Neck–APECS Neck	$y = 6.25 + 0.73x$	0.251	Positive linear

Visual inspection of the scatterplots demonstrated positive linear relationships between all QEC and APECS variables without substantial deviation from linearity. These findings indicated that the assumption of linearity was met, supporting the application of Pearson correlation analysis.

Pearson correlation analysis was subsequently performed to evaluate the associations between unilateral loading and neck and shoulder asymmetry. The results are presented in Table 8.

Table 8. Pearson Correlation Analysis Between Unilateral Loading and Postural Asymmetry

Variables	r	95% CI	p value	Interpretation
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QEC Shoulder–APECS Neck	0.544	0.221–0.760	0.002	Moderate
QEC Shoulder–APECS Shoulder	0.757	0.546–0.878	0.003	Strong
QEC Wrist–APECS Neck	0.534	0.208–0.754	0.002	Moderate
QEC Wrist–APECS Shoulder	0.804	0.625–0.903	0.003	Very strong
QEC Neck–APECS Neck	0.501	0.167–0.735	0.005	Moderate
QEC Neck–APECS Shoulder	0.760	0.550–0.879	0.004	Strong

Pearson correlation analysis demonstrated statistically significant positive associations between all unilateral loading variables and neck and shoulder asymmetry ($p < 0.05$). Shoulder/arm loading showed a moderate correlation with neck asymmetry and a strong correlation with shoulder asymmetry. Wrist loading exhibited the strongest association with shoulder asymmetry ($r = 0.804$, 95% CI: 0.625–0.903, $p = 0.003$), whereas neck loading demonstrated moderate to strong positive correlations with both neck and shoulder asymmetry. Overall, higher unilateral loading levels were consistently associated with greater neck and shoulder asymmetry among the participants.

Discussion

The present study demonstrated significant positive associations between unilateral water container carrying and the risk of neck and shoulder asymmetry among adolescents. Higher levels of unilateral loading were consistently associated with greater postural asymmetry, indicating that repetitive asymmetric loading may adversely affect musculoskeletal alignment during adolescence. The strongest association was observed between wrist loading and shoulder asymmetry, suggesting that mechanical loading transmitted through the upper extremity substantially influences shoulder alignment. These findings support the hypothesis that habitual unilateral load carrying contributes to postural alterations and reinforce the importance of ergonomic interventions to minimize musculoskeletal risks in rural adolescents.

The observed associations can be explained by the biomechanical adaptations required to maintain balance during unilateral load carriage. Carrying a water container on one side of the body shifts the center of gravity toward the loaded side, requiring continuous activation of the cervical, shoulder, and trunk stabilizing muscles to preserve postural equilibrium. Repetitive asymmetric muscle activation may gradually increase mechanical stress on the cervical spine and shoulder girdle, resulting in altered muscle length, increased passive tissue tension, and compensatory postural deviations. Over time, these adaptations may contribute to persistent neck and shoulder asymmetry, particularly during adolescence when the musculoskeletal system is still undergoing structural growth and functional maturation. These findings are consistent with previous reports demonstrating that unilateral load carriage induces compensatory postural adjustments and increases the risk of musculoskeletal imbalance.²

The finding that wrist loading demonstrated the strongest association with shoulder asymmetry highlights the importance of considering the upper-limb kinetic chain during ergonomic assessment. Mechanical forces generated at the hand and wrist are transmitted proximally through the forearm and elbow to the shoulder complex, thereby increasing the demand placed on the scapular stabilizers and cervical musculature. Continuous exposure to unilateral loading may therefore promote shoulder elevation and asymmetrical alignment as compensatory mechanisms to maintain stability during locomotion. Similar biomechanical responses have been described in previous investigations evaluating unilateral load carriage, which reported alterations in body alignment, balance, and movement patterns following repetitive asymmetric loading.^{2,7}

The present findings are also in agreement with studies reporting that repetitive unilateral loading increases the likelihood of postural asymmetry and musculoskeletal disorders.⁸ Previous investigations have demonstrated that asymmetric load carriage modifies body mechanics by altering load distribution and increasing muscular activity on one side of the body, thereby predisposing individuals to postural deviations and discomfort.^{4,9} The significant correlations identified in this study further support the ergonomic principles underlying the Quick Exposure Check (QEC), which proposes that increasing exposure to mechanical loading is associated with greater musculoskeletal risk. Furthermore, the use of the AI Posture Evaluation and Correction System (APECS) enabled objective digital quantification of neck and shoulder asymmetry, complementing the ergonomic assessment provided by the QEC and strengthening the interpretation of the study findings.

From a clinical perspective, these findings emphasize the importance of preventive strategies targeting adolescents living in rural communities where manual water transportation remains part of daily life. Ergonomic education should encourage alternating the carrying side, limiting the weight of water containers according to individual physical capacity, improving carrying techniques, and reducing prolonged unilateral loading whenever possible. Physiotherapists, schools, and community health workers may play an important role in promoting postural awareness and early musculoskeletal screening to reduce the long-term consequences of repetitive asymmetric loading.¹⁰

Several limitations should be acknowledged when interpreting the findings of this study. First, the cross-sectional design precluded the establishment of causal relationships between unilateral loading and postural asymmetry. Second, the relatively small sample size and purposive sampling technique may limit the generalizability of the findings to other populations. Third, only neck and shoulder asymmetry were evaluated, whereas other postural parameters, such as spinal curvature, pelvic alignment, and lower-extremity biomechanics, were not assessed. Finally, potential confounding variables, including body mass index, carrying duration, carrying frequency, physical activity level, hand dominance, and water container weight, were not statistically controlled. Future longitudinal studies involving larger and more diverse populations are recommended to clarify causal relationships and evaluate the long-term effects of repetitive unilateral loading on musculoskeletal health.¹¹

Conclusion

This study demonstrated significant positive associations between unilateral water container carrying and the risk of neck and shoulder asymmetry among adolescents. Higher levels of unilateral loading were consistently associated with greater postural asymmetry, indicating that repetitive asymmetric loading may adversely affect musculoskeletal alignment during adolescence. Among the evaluated loading components, wrist loading exhibited the strongest association with shoulder asymmetry, suggesting that forces generated during unilateral load carriage are transmitted throughout the upper-limb kinetic chain and contribute to compensatory postural adaptations.

These findings provide evidence that habitual unilateral water container carrying represents a potential ergonomic risk factor for postural alterations among adolescents living in rural communities. Early identification of postural deviations and the implementation of preventive ergonomic strategies may help minimize long-term musculoskeletal complications associated with

repetitive unilateral loading. Future longitudinal studies involving larger populations and additional biomechanical variables are recommended to clarify causal relationships and evaluate the long-term effects of unilateral loading on musculoskeletal health.

Author Contribution

Patricia Jeanne D'arc Suwardi: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft.

I Gede Arya Sena: Methodology, Validation, Supervision, Writing – Review & Editing.

Ni Putu Dwi Larashati: Methodology, Validation, Writing – Review & Editing.

Ni Luh Reny Wahyu Sari: Supervision, Project Administration, Writing – Review & Editing.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this study.

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Ethics Statement

This study was approved by the Research Ethics Committee of Universitas Dhyana Pura, Indonesia (Ethical Approval No. 001297/KEP Universitas Dhyana Pura/2026). All procedures involving human participants were conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to their enrollment in the study.

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