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# FITNESS ASSESSMENT OF SAFETY HELMETS USED BY CONSTRUCTION WORKERS IN DEVELOPING COUNTRIES – THE CASE OF GHANA

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## ABSTRACT

***Purpose:*** *Poor-fitting helmets frequently cause discomfort among construction workers, potentially distracting them and compromising their safety. This paper investigates safety helmet fit issues amongst Ghanaian construction workers.*

***Design/Methodology/Approach:*** *Linear head measurements were collected from one hundred and twenty-seven (127) male construction workers. These measurements were then compared with the internal dimensions of construction helmets available in Ghana, considering both maximum and minimum adjustments. A two-sample T-test was employed for the analysis.*

***Findings:*** *The study results revealed statistically significant differences between the dimensions of safety helmets in the country and the head measurements of the study participants.*

***Research Limitation/Implications:*** *A limitation of this study is that head measurements were obtained exclusively from male construction workers, as no female workers were present at the sites during the data collection period.*

***Originality/Value:*** *The study's findings indicate that the dimensions of safety helmets available in the country do not offer an adequate fit for indigenous male heads, even though they are adjustable. The study recommends considering the anthropometric features of target users as a critical factor in the procurement and importation of safety helmets to improve the experience among construction workers.*

**Keywords:** Anthropometric features, poor fit, safety helmets, safety protection.

## INTRODUCTION

The safety performance of the construction industry remains a critical concern, particularly as work-related accidents and fatalities persist despite extensive research aimed at enhancing safety measures (Li et al., 2017; Zhou et al, 2015). These incidents adversely impact project timelines, budgets, quality, and worker productivity, with poor safety practices often cited as a principal cause (Khalid et al., 2021). Construction-related injuries, particularly in developing countries, remain alarmingly high. Studies from South Africa (Okoro et al., 2016), Nigeria (Muktar and Chinyio, 2016; Agwu and Olele, 2014), and Ghana (Akomah et al., 2012), highlight this issue. Malaysia has seen a 55.7% increase in construction accidents and a 74% rise in fatalities from 1993 to 2014 (Hamid et al., 2019).

The dynamic and often hazardous work environments on construction sites make workers particularly vulnerable to head injuries from falls or being struck by objects. Because of their potential severity and long-term consequences, head injuries are a focal point of occupational health within the construction sector (Li et al., 2017). This focus is as a result of the risk of Traumatic Brain Injuries (TBIs), which are recognized as a substantial health issue worldwide (Daughton 1990; Trout et al., 2022). According to the National Institute for Occupational Safety and Health (NIOSH), the prevalence of TBIs in the construction industry surpasses other industries in some countries, with the U.S. construction industry recording the highest number of TBIs (Tiesman et al., 2011; NIOSH, 2016). From 2003 to 2010, the construction sector witnessed 2,210 fatal TBIs at a rate of 2.6 per 100,000 full-time equivalent workers (Konda et al., 2016), with older workers facing the greatest risk. More recent data from other countries demonstrates that TBIs remain a persistent challenge in the construction setting globally. A study examining TBI incidents between 2014 to 2018 in Sweden and Germany revealed average annual rates of 9 per 100,000 full-time equivalent and 117 per 100,000 full-time equivalent respectively (Brolin et al., 2021). Further research by Kim et al. (2018) underscores this trend, indicating that in 2016, out of 391 reported injuries at construction sites, head injuries were disproportionately represented, accounting for 41% of cases. A separate retrospective analysis on outpatient work-related TBIs revealed that nearly one-fifth (19.1%) of these injuries occurred among individuals in the construction field, a group that predominantly includes both skilled and unskilled labourers, often with a high school education or less. These workers, especially those new to the industry, showed a higher susceptibility to TBIs (NIOSH, 2016). While comprehensive local TBI surveillance data is not available due to limitations, these international figures emphasize the ongoing significance of TBI risk in the construction industry worldwide. The vital role of safety helmets in mitigating such injuries is clear. They are designed to protect by absorbing and distributing impact energy, withstand penetration and in some cases protect against electric shock to protect the head area from the impact of contact with hazards, (Jachowicz, 2013; Nill, 2019).

However, Ellena et al., (2016) assert that the protective benefits offered by helmets are compromised when they are not correctly adjusted to fit the wearer’s head. Kim et al. (2018) further emphasizes this by noting that when safety helmets are worn properly, they can effectively reduce the impact force to the wearer’s head to less than 10% of the impact force, underscoring the importance of proper helmet usage for optimal protection. Advancements like sensor-equipped helmets have been proposed (Kim et al., 2018), to ensure the accurate wearing of safety helmets.

However, for personal protective equipment (PPE) like safety helmets to work as intended, they must fit properly. Unfortunately for indigenes of many developing countries, there is often a gap between the design standards, which are usually based on data from more industrialized nations, and the actual physical measurements of workers in less industrialized parts of the world. This gap can lead to PPE that does not fit right, which then tends to be used less frequently or not at all (Abeysekera and Shahnavaz, 1989; Adade-Boateng et al., 2016). Studies from Ghana indicate the practical consequences of ill-fitting helmets, with workers reporting discomfort and frequent removals for relief (Adade-Boateng et al, 2017; 2023). According to Adade-Boateng et al. (2017), construction workers indicated that helmets fit so badly that even though they were adjustable, they had to be taken off occasionally just to feel more comfortable. One worker lamented, “my head is very small and so even though I adjust it, it keeps dropping down my face”. Some workers mentioned that the top part of their scalp was constantly scratched by the harness, especially plastic ones (Adade-Boateng et al, 2017).

These findings suggest that imported adjustable helmets may be failing to accommodate the range of head sizes within the country, underscoring the need for designs tailored to the local workforce as they are at higher risk for TBIs because of their work in dynamic environments where they can be struck by falling and flying objects or fall from elevated heights (Trout et al., 2022). This study further investigates this potential mismatch of head sizes and helmets by comparing the head measurements of Ghanaian construction workers to the dimensions of commonly used imported safety helmets. By doing so, it aims to explore how accommodating safety helmets are, among Ghanaian construction workers to potentially inform design improvements, improved considerations for their importation and enhanced safety compliance.

## MATERIALS AND METHOD (METHODOLOGY)

The study employed a quantitative research method to investigate the fit issues with safety helmet use amongst Ghanaian construction workers. The methodological choice facilitated the collection of data from a substantial sample size, enhancing generalizability and allowing for the application of statistical analysis techniques to interpret data (Leavy, 2017). Survey, case study and experimental research are constituents of the quantitative research methodology (Tan, 2022; Creswell and Creswell, 2023).

According to Ganesha and Aithal (2022), an experimental procedure allows researchers to gather data designed to either test, corroborate or refute an assumption surrounding a phenomenon. A cross-sectional research design was selected to collect anthropometric data from construction workers and compare these measurements with the dimensional specifications of safety helmets available on the market. This allowed for statistical comparison between workers’ head dimensions and safety helmet specifications, providing a basis for issues relating to the fitting of helmets. The study followed a structured procedure involving participants’ recruitment, anthropometric measurements of workers’ heads, collection of safety helmet dimensional data, and statistical analysis to determine the significance of any discrepancies between head and helmet measurements.

## Case Study Selection and Safety Helmet Sampling

The study employed a multiple case study approach focusing on three construction sites in Kumasi. The case sites were involved in the construction of multi-storey public buildings. Site selection criteria included: (1) active construction status with ongoing construction project and a minimum of thirty workers on site; (2) strict enforcement of Personal Protective Equipment (PPE) policies on sites; (3) willingness of management to undertake the research.

The focus on sites with established safety protocols ensured that participants were familiar with proper safety helmet adjustments and usage, minimizing measurement errors that might arise from improper handling. Within the case study sites, one hundred and twenty-seven (127) construction workers volunteered to participate in the study following detailed orientation sessions about the study's purpose, methodology, and potential benefits. Participants in the study represented various roles like masons, carpenters, steel benders, labourers among others, providing a comprehensive perspective on helmet fit issues across different construction specialization.

Safety helmets were sampled through a comprehensive open market survey of helmet importers conducted in Ghana, namely Accra, Kumasi and Takoradi. These cities have relatively developed infrastructure and serve as a hub for construction firms and economic activity. Together, they represent the primary centres of construction activities in Ghana, ensuring that helmets included in the study represented those commonly available to and used in Ghanaian construction sites to ensure consistency in data collection.

## Data Collection

Anthropometric data collection followed a standardized protocol to ensure the accuracy and consistency in measurements. Adopting the head measurements modality in wig cap manufacturing, head dimensions were measured using a non-stretchable measuring tape that was carefully contoured to the scalp to capture the true head shape of participants. During this session, the tape was kept firm but not tight to avoid scalp compression while ensuring accurate readings. The following key anthropometric measurements as depicted in Figure 1, were recorded for each participant:

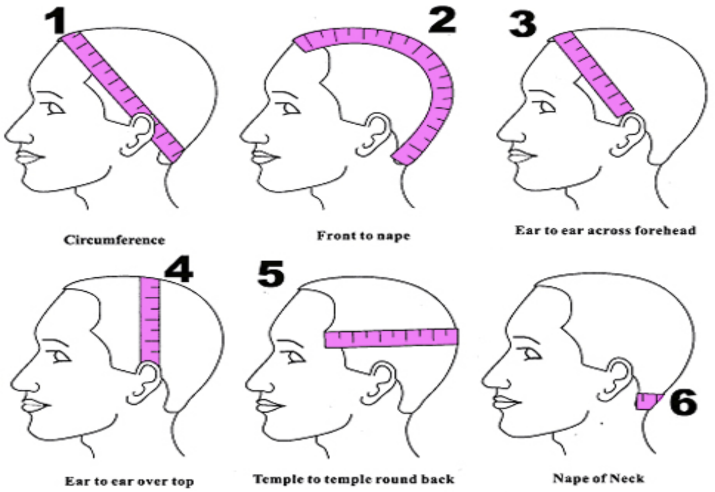


Figure 1: Heads measurement modality used in the manufacture of wig caps

1. **Head circumference:** horizontal measurement around the widest part of the head;
2. **Sagittal arc (front to nape):** measurement spanning from the glabella (i.e. between eyebrows) to the nape of the neck;
3. **Frontal arc (ear to ear across forehead):** measured across the forehead from the superior attachment of one ear to the other;
4. **Coronal arc (ear to ear over top):** measured from one ear canal, over the crown of the head, to the opposite ear canal;
5. **Occipital arc (temple to temple round back):** measurement spanning from one temple, through the occipital region at the back of the head, to the opposite temple;
6. **Nape of neck distance:** vertical distance from one point of the nape to the other.

Each measurement was taken twice, and was systematically recorded in a specifically designed spreadsheet. After entering data, the average value of the measurements was computed in order to minimize measurement related errors. The collected data were then used for this study. Subsequently, measurements were conducted on the interior dimensions of the sampled safety helmets. The measurements of the adjustable features of safety helmets, including both maximum and minimum dimensions were recorded. This data collection was essential to draw comparisons between the head circumferences of the volunteers and the size ranges that the adjustable helmets can accommodate.

## Data Analysis

Recording to all anthropometric and helmet measurements were systematically recorded in a dedicated spreadsheet that facilitated data organization and analysis. This spreadsheet included sections for participants' demographics, anthropometric measurements, and helmet specifications. Descriptive and inferential statistical methods were used to analyse data. While the descriptive statistics provided a comprehensive overview of the head dimension characteristics within the sample population and the dimensional specifications of available safety helmets, the inferential statistics using a two-sample t-test sought to establish whether there were significant differences existing between workers' head and the dimensions of available safety helmets. Using the Statistical Package for Social Sciences (version 25), the two sample t-test was conducted at a 95% confidence level. To this end, the null hypothesis ($H_o$) stated that there was no significant difference between the mean head dimensions of construction workers and the corresponding dimensions of safety helmets on the market. The alternative hypothesis ($H_1$) stated that a significant difference existed. Informed consent was obtained from all participants before data collection. All personal data was kept confidential and was solely used for research purposes.

## RESULTS AND DISCUSSION

Twenty-three (23) different types of construction safety helmets and one type of bump cap were discovered in the open market survey conducted in Accra, Kumasi and Takoradi. Out of these, only seventeen (17) were labeled with a brand name and the international standards to which they conform. Except for two types of helmets that had fabric interwoven with plastic in the suspension system, the remaining helmets had different types of plastic suspension systems. The importers indicated that the safety helmets were usually imported from the United States of America, Europe, and China. The suppliers also indicated that most construction companies in the country, usually bought helmets that were least priced, and these were usually non-branded.

Summary statistics of safety helmet and head dimensions measured from 127 volunteer construction workers as well as that obtained from the helmets are shown in Table 1 below:

**Table 1: Summary Statistics of Head Measurements (HM)**

| HEAD MEASUREMENTS (HM)/mm | | | | | | |
|---|---|---|---|---|---|---|
| **Description** | | **Mean** | **Median** | **Std. Dev.** | **Min** | **Max** |
| Head circumference | HM1 | 55.60 | 56.00 | 3.72 | 38.00 | 65.30 |
| Sagittal arc | HM2 | 33.40 | 34.00 | 3.14 | 21.00 | 38.00 |
| Frontal arc | HM3 | 27.20 | 30.00 | 7.04 | 10.00 | 35.00 |
| Coronal arc | HM4 | 28.90 | 32.00 | 7.94 | 9.00 | 37.00 |
| Occipital arc | HM5 | 32.40 | 35.00 | 8.27 | 12.00 | 46.00 |
| Nape of neck distance | HM6 | 11.50 | 12.00 | 3.45 | 3.00 | 19.00 |

**Table 2: Summary Statistics of Safety Helmet Measurements (SH)**

| Safety Helmet (mm) | | | | | |
|---|---|---|---|---|---|
| **Description** | **Mean** | **Median** | **Std. Dev.** | **Min** | **Max** |
| HM1 | 61.47 | 65.00 | 1.33 | 49.00 | 66.00 |
| HM2 | 32.53 | 32.00 | 2.21 | 27.00 | 38.00 |
| HM3 | 28.97 | 28.50 | 1.55 | 27.50 | 32.50 |
| HM4 | 28.91 | 27.50 | 1.52 | 22.00 | 31.00 |
| HM5 | 29.91 | 27.50 | 3.70 | 25.00 | 37.00 |
| HM6 | 8.65 | 9.50 | 2.76 | 4.00 | 20.00 |

**Table 3: Results of Two Sample T-Test between Head Measurements and Safety Helmets**

| Description | N | Mean | Std Dev. | P-Value |
|---|---|---|---|---|
| Head Measurement 1 | 24 | -6.61 | 0.79 | 0.00 |
| Head Measurement 2 | 24 | 1.59 | 0.67 | 0.20 |
| Head Measurement 3 | 24 | -1.65 | 1.45 | 0.26 |
| Head Measurement 4 | 24 | 0.71 | 1.64 | 0.67 |
| Head Measurement 5 | 24 | 3.04 | 1.73 | 0.08 |
| Head Measurement 6 | 24 | 1.96 | 0.81 | 0.02 |

Table 1 presents statistical data on six different head measurements (HM1 to HM6), comprising the mean, median, standard deviation, minimum (Min), and maximum (Max) values for each measurement. The head measurements show a range of distributions and variability. HM1 has the highest measurements on average, while HM6 has the lowest. The standard deviations indicate that HM3, HM4, and HM5 have more variability in their measurements compared to HM1, HM2, and HM6. The median values being higher than the means for HM3, HM4, and HM5 suggest a left-skewed distribution, indicating a larger number of smaller measurements.

The wide ranges in HM3, HM4, and HM5, as indicated by their standard deviations and the difference between their minimum and maximum values, suggest that the data for these measurements might be more spread out or may contain outliers.

Table 2 presents summary statistics for six helmet measurement parameters (HM1 to HM6) such as those recorded from the heads of volunteers. HM1 exhibits the highest mean (61.47 mm) and range (49.00–66.00 mm), HM2 and HM3 show relatively consistent and symmetrical distributions with moderate means around 29–33 mm and small standard deviations. HM4 and HM5 display slight right skewness, with HM5 having a higher variability (Std. Dev = 3.70 mm). HM6, although having the smallest mean (8.65 mm), shows notable variability and a wide range (4.00–20.00 mm). Overall, the data indicates differences in consistency and distribution across the helmet dimensions, with some measures potentially affected by outliers or non-uniformity.

Table 3 presents results obtained from two sample t-test at a 95% confidence level. Based on the results shown in the table, the significant p-value ($p = 0.00$) of Head Measurement 1(HM1) strongly suggests that this head measurement is significantly different from the comparison sample. The negative mean could imply that this measurement was, on average, lower than the reference value by 6.61 units. This suggests that the helmet poorly fits the sampled population, potentially compromising workers' safety. This discrepancy suggests a poor fit, specifically that the helmet would be excessively loose for the sampled population in this dimension, potentially compromising its protective function. Head Measurements 2, 3, and 4 have p-values (0.20, 0.26, and 0.67 respectively) above the conventional threshold for significance (0.05). This suggests that the mean differences for these measurements are not statistically significant. Head Measurement 5 (HM 5) has a p-value of 0.08, which is marginally above the significance threshold. This suggests a possible trend, as it is close to the conventional cut-off, indicating that there may be a difference, but the sample does not provide enough evidence to confirm it is statistically significant. It might be worth investigating further with a larger sample size.

Head Measurement 6 (HM6) with a p-value of 0.02 indicates statistical significance, suggesting that this measurement's mean is reliably different from the comparison value.

The findings from this investigation highlight a discrepancy in the fit of safety helmets available to male construction workers in Ghana as measured against their actual head dimensions. The study discovered that a significant number of the helmets are not adequately accommodating the range of head sizes, with some head measurements falling below the minimum adjustment parameter of the helmets sourced from local markets and construction sites (e.g., Head Measurement 5 (HM5) from our volunteers often surpassed the largest internal dimension available in the helmets).

This discovery aligns with long-standing concerns regarding the sizing and fitting of PPE in developing economies, which were raised by some early scholars, such as Abeysekera and Shanahvaz (1988), and subsequently confirmed by Onyebeke et al. (2016) and Al-Bayati et al. (2023). This dimension mismatch is not just a matter of numbers; it is a reflection of a real-world issue that can compromise the protective function of helmets in developing countries due to improper fit. Indeed, the discomfort reported by workers, as noted by Adade-Boateng et al. (2018), is likely symptomatic of this ill fit, which could lead to reduced usage compliance and increased risk of injury.

Helmets that do not fit properly may contribute to workers experiencing sporadic headaches, a condition observed in research such as that by Adade-Boateng et al. (2017). These headaches, which bear resemblance to external compression headaches (ECH), often go unreported and are not officially recorded. Yet, the symptomatic relief workers feel upon helmet removal points to the connection between these headaches and the pressure exerted by tight helmets. The tendency of workers to frequently remove their helmets to relieve this discomfort substantially raises the risk of accidents and injuries on construction sites. Moreover, the persistent use of such helmets by those presenting symptoms of ECH could lead to additional health complications, further underscoring the necessity for correctly sized and comfortable protective headgear in the workplace. The implications of these findings are twofold.

Firstly, they call for a reassessment of the design and distribution of safety helmets to ensure a more inclusive range of sizes that better align with the anthropometric reality of the worker population in Ghana and other developing countries.

Secondly, they emphasize the need for regulatory bodies to enforce standardized fitting tests, ensuring that helmets distributed in the market are capable of providing adequate protection for all wearers. Current international standard (e.g. ISO 3873-2025) and regionals standards (e.g. ANSI Z89.1-2014 and EN397:2012) governing industrial helmet fitting tend to establish baseline requirements, predominantly reflecting anthropometric data from Western populations and may not adequately address the head dimensions found in diverse global populations. In Ghana specifically, the adoption of these international standards occurs without local adaptation, creating a disconnect between available helmet sizes and actual worker anthropometry.

This study’s insights should encourage manufacturers and safety regulators to consider customizing helmet designs to cater to the diverse anthropometric needs of construction workers in different geographical locations, enhancing both safety and comfort on job sites. Moreover, incorporating standardized fitting tests tailored to local anthropometric characteristics into the procurement process would help ensure that helmets acquired and used in developing countries offer optimal protection for their users.

## CONCLUSION

In conclusion, this research has revealed a significant gap in the design and distribution of safety helmets, particularly in the global south, including the study's location. This gap, highlighted by Gupta (2014), stems from a lack of effective communication between ergonomists and PPE designers, as well as the prevalent practice of manufacturing PPE in developed countries without sufficiently considering the anthropometric data of the intended users from developing regions. Such oversights have been underscored by the discomfort workers experience, which can lead to unintentional non-compliance and subsequent avoidable accidents.

The statistical evidence from this study, alongside the firsthand accounts of discomfort such as scalp irritation, headaches, and excessive sweating reported by Adade-Boateng et al. (2018), underscore the critical need to address fit issues during the procurement of safety helmets. There is a pressing call for a paradigm shift towards integrating regional anthropometric data into the design and selection process of PPE.

This study supports the notion that better-fitted safety helmets are not just a matter of comfort but of safety and could substantially increase compliance with their use, thus enhancing the overall well-being and productivity of construction workers.

Moving forward, PPE stakeholders must consider these findings in the pursuit of not just compliance, but the genuine safety and comfort of workers. The study emphasizes the importance for developing countries to systematically collect and analyse anthropometric data of their populations. Such data should inform the design, manufacturing, importation, or procurement processes of safety helmets to ensure they meet the specific fit requirements of the workforce.

Furthermore, it is recommended that developing countries engage in additional research that targets the creation of standards that align with their unique environmental conditions and the physical attributes of their citizens. This will support the development or importation of safety equipment that is not only effective but also comfortable for the user, ultimately fostering a safer work environment through increased compliance.

Additionally, the study recommends the national stakeholders, particularly policy-makers in developing economies, to create incentive packages and support systems to establish local PPE manufacturing facilities to ensure supply chain of quality PPEs are available to the local workforce. These recommendations highlight the critical role of tailor-made safety solutions in addressing the health and safety needs of workers, especially in contexts where off-the-shelf PPE may not be suitable due to varying body dimensions and workplace conditions. The research scope was limited to a volunteer group of one hundred and twenty-seven (127) male construction workers since no female workers were encountered on the sites.

This limits the generalizability of the findings by excluding the anthropometric challenges faced by female construction workers (Onyebeke et al., 2016). Although they present a small fraction in the workforce, a comprehensive safe workplace needs to adequately address their specific needs as well. To start with, trade unions and other stakeholders can foster gender inclusion and safety on sites by making procurement decisions that consider diverse sizing and ergonomic needs, particularly for women.

However, simply adjusting procurement practices may not be sustainable in the long term.

It is essential to first understand the sexual dimorphism in head and face dimensions of women and men. As a consequence of this biological difference, the mean differences and suggested design tolerances of safety helmets derived from the participants may not be safety designed to fit the female's anthropologic characteristics. This limitation suggests an area for future research to encompass a more diverse participant group and a broader market analysis to fully understand the PPE fit issue across the entire workforce.

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## DECLARATION OF CONFLICT OF INTEREST

None.

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