Clinical characteristics and outcomes of injuries of farmers and non-farmers visiting the emergency department: A propensity-matched analysis

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Abstract

Objective: Agriculture is one of the most hazardous industries. However, previous studies have mainly focused on injuries in agricultural workers and have not compared with injuries in non-agricultural workers. Thus, we aimed to compare the clinical characteristics and outcomes of injuries in agricultural workers compared to non-agricultural workers reported at the emergency department (ED).

Methods: We established a prospective ED-based agricultural injury surveillance system at a tertiary university hospital. The adult injured patients visiting ED were divided into farmer and non-farmer groups depending on the agricultural engagement. Using adjusted multivariate analysis and propensity score matching (age, gender, inhabitant, and insurance type), we compared the clinical characteristics and outcomes of injuries among farmer vs. non-farmer group.

Results: 38,556 adult injured patients (37,746 in non-farmer group and 810 in farmer group) were available for unmatched sample analysis. The 1,620 matched subjects were equally classified after 1-to-1 nearest neighbor propensity score matching. Multivariate logistic regression analysis of the unmatched sample revealed higher adjusted ORs for intensive care unit admission (adjusted OR: 1.752, p=0.003) and overall surgery (adjusted OR: 1.870, p<0.001) for farmers. In contrast, a univariate logistic regression analysis of the propensity score-matched sample found only a higher OR of overall surgery (OR: 1.786, p<0.001) in the farmer group.

Conclusions: Injuries in agricultural workers only had higher odds of overall surgery, while the differences in mortality were not statistically significant in both the matched and unmatched sample analyses.

Keywords: Occupational Injuries, Wounds and Injuries, Farmers, Propensity Score, Agriculture

Capsule summary

(1) What is already known

Agriculture is a hazardous industry that employs the largest number of workers globally. Previous studies have reported higher mortality and morbidity rates in agricultural workers. However, few have performed a direct comparative analysis with workers in other industries as a comparator group.
What is new in the current study

This study compared injury outcomes between farmers and non-farmers using a prospective ED-based surveillance system with propensity matching. Results showed only surgery prevalence differed significantly. Multivariate logistic regression analysis, adjusted for confounding factors, found no significant difference in mortality between the two groups. Univariate logistic regression analysis using the propensity score-matched sample revealed that only the prevalence of surgery was significantly higher in the farmer group.
Introduction

Agriculture is an essential industry that provides the basic needs of society, and employs the largest number of workers globally, compared to all other industries [1]. Although the industrial structure and population distribution in Korea have changed since the advent of modern industry, agriculture remains the main industry in many provinces, with about 2.3 million farmers engaged in agriculture in 2020 [2]. Acute injuries in agricultural workers have consistently been ranked as among the highest in all industries along with transportation and construction [3–5]. In addition, fatality rates for agricultural workers in many countries, including the United States, European Union, and South Korea, are invariably several times greater than the average rate for all industries combined [6–8]. In 2019, approximately 22.2 million full- and part-time workers were employed in production agriculture and food industries in the US. About 410 farmers and farm workers died from a work-related injury, resulting in a fatality rate of 19.4 deaths per 100,000 full-time workers in the US in 2019 [8]. According to the Korean Farmers’ Occupational Disease and Injury Survey (KFODIS), 48,405 farmers suffered an injury that required more than 1 day of absence during the previous year. The estimated prevalence of injuries among Korean farmers was 2.7% in 2019 [9]. Although agricultural workers are at a very high risk for fatal and non-fatal injuries, there has been little concern about studying health and safety in the agricultural setting until recently. Injuries in agricultural workers stem from a complex chain of inherent factors, including human (cultural), environmental, and agent factors [10,11]. It is therefore imperative to study the unique epidemiology of injuries in agricultural workers as compared to injuries in other industries’ workers. However, most of previous studies focused only on agricultural workers as the study population, and relatively few studies have performed a direct comparative analysis with workers in other industries’ as a comparator group [12–17]. Thus, information about the clinical aspects of injuries in agricultural workers as distinct from other industries’ workers remains unclear due to the limited appropriate data sources. This study set out to compare the clinical characteristics and outcomes of injuries between agricultural workers and non-agricultural workers visiting the emergency department (ED) by establishing a prospective ED-based agricultural injury surveillance system (ED-AgISS).
Materials and Methods

Study Design and Setting

We conducted a retrospective analysis using the prospective registry of the ED-AgISS of the Safety for Agricultural Injury of Farmers (SAIF) study at a tertiary university hospital. SAIF is a comprehensive community- and hospital-based study investigating occupational and environmental exposures affecting the epidemiology of agricultural injury and their outcomes among farmers residing on Jeju Island and is supported by the Jeju Center for Farmers’ Safety and Health of the Korean Ministry of Agriculture, Food, and Rural Affairs.

The ED-AgISS was designed as an additional module for the existing ED-based Injury Surveillance System (EDISS), with the aim of providing in-depth occupational injury surveillance for agricultural workers. The Korea Centers for Disease Control and Prevention (KCDC) established the EDISS in 2006 to build a national injury monitoring, with a nationwide multicenter prospective registry to investigate general injury epidemiology at 23 EDs of tertiary hospitals in 2022 [18].

The ED-AgISS was implemented in October 2015 as a two-step in-depth injury surveillance focused on better capturing farmers’ occupational injuries. Details of registry information (standard and expanded data sets) were collected differently, depending on occupation (farmers and non-farmers) by a two-step investigation process.

This study was reviewed and approved by the Institutional Review Board of XXX University Hospital (approval number. 2018-07-011), with a waiver for the need to obtain informed consent.

Selection of Participants

Our eligible study population consisted of all adult injured patients who visited the ED of XXX University Hospital between October 1, 2015, and December 31, 2020. The diagnostic codes of the eligible population were consistent with any one of the following: “injury, poisoning, and certain other consequences of external cause (S00-T88)” of the International Classification of Diseases, 10th Edition (ICD-10) [19].

The included study population was 18 years of age or older on the day of the incident and was divided...
into farmer and non-farmer groups. Patients who died on arrival at the ED and whose injury severity or final clinical outcome could not be determined were excluded from the final analysis.

**Data Collection**

The primary purpose of ED-AgISS is to capture the occupation (farmers vs. non-farmers) of injured patients visiting the ED, with the omission of as few cases as possible. To achieve this, the status of engagement in agricultural work was confirmed for all injured patients by independent investigators of the Jeju Center for Farmers’ Safety and Health at XXX University Hospital.

The ED-AgISS registry was designed to collect comprehensive information on the following domains in a two-step injury surveillance system: 1) a standard dataset for general injury epidemiology from EDISS (step one) and 2) an expanded dataset for occupational injury epidemiology of agricultural workers (step two). After obtaining standard data from all injured patients visiting the ED routinely in the first step, according to the EDISS, expanded data of injured patients confirmed to be engaged in agricultural work were further investigated in the second step.

The standard dataset from EDISS included socio-demographics (age, sex, insurance type, vital signs, and mental status), injury characteristics (intention, mechanism, activities, places, emergency medical service [EMS] usage, and whether the injury was alcohol-related), diagnosis, injury severity index (revised trauma score [RTS], injury severity score [ISS]), emergency care process with a time log, treatment, and disposition (discharge, interhospital transfer, admission, death) at the hospital [18].

The expanded dataset included the characteristics of injuries in agricultural workers based on the occupational injury and illness classification system and agricultural work-related conditions (types of farming, total farming career experience, in-depth category of places, protective devices, and agricultural machinery) [20]. (supplementary material: ED-AgISS expanded survey paper)

**Outcomes of Interest**

Our primary outcome measures in this study were binary indicators of in-hospital 7-day mortality, 14-day mortality, and overall mortality.

The secondary outcomes were indication for surgery (yes/no) within the first 72 h and admission to the intensive care unit (ICU), in terms of the urgent utilization of special medical resources.
**Statistical Analysis**

We estimated the propensity scores for each participant using a multivariate logistic regression model of the odds of being allocated to either the farmer or non-farmer group, in which baseline demographics (age, sex, inhabitant, and insurance type) and year of injury were the predictors for the matching criteria. Because of the temporal order associated with a causal relationship, only variables prior to the injury incident were considered as predictors.

We matched each patient in the farmer group with a patient in the non-farmer group by propensity scores, using 1-to-1 nearest-neighbor matching without replacement, within a caliper size of 0.2, which resulted in pairs of patients in the matched sample.

Numerical and graphical diagnostics were performed to compare the extent of balance between the two groups in the data set before and after propensity score matching [21,22]. For each variable used in the matching process, we performed the following analyses: t-tests for comparing the equality of means in the two samples, the standardized percentage bias before and after matching with the achieved percentage reduction, and the variance ratio of the farmer group to the non-farmer group. We also calculated the following overall measures of covariate imbalance before and after propensity score matching: Pseudo $R^2$ from the probit estimation of the conditional treatment probability (propensity score) for all the variables, with the corresponding P-values of the likelihood-ratio test of the joint insignificance of all the regressors; the mean bias as summary indicator of the distribution of the absolute bias; Rubins’ B (the absolute standardized difference of the means of the linear index of the propensity score in the treated and non-treated groups), and Rubins’ R (the ratio of treated to non-treated variances of the propensity score index). If B was less than 25 and R was between 0.5 and 2 for the samples, the groups were considered sufficiently balanced [23].

We calculated descriptive statistics for the baseline demographics, injury epidemiology, and clinical outcomes of the study population stratified by occupation (farmers and non-farmers), before and after propensity score matching. Descriptive statistics are presented as frequencies and percentages for categorical variables and as means ± standard deviations or medians with interquartile ranges for continuous variables, depending on the distribution.
Univariate analysis in both unmatched and matched samples was conducted for each variable of baseline demographics, injury epidemiology, and clinical outcomes between the two groups using Student’s t-test, Wilcoxon’s rank-sum test, and the chi-squared test or Fisher’s exact test, as appropriate. In the unmatched sample, multivariate logistic regression analysis adjusted for potential confounders (age, sex, inhabitant, insurance type, year of injury) was used to identify whether occupation affected dichotomous primary and secondary outcomes between the farmer and non-farmer groups. A secondary analysis using bivariate logistic regression was employed in the propensity score-matched sample to identify the relationship between occupation and outcomes of interest.

All statistical analyses were performed using Stata 17.0 (StataCorp, College Station, TX, USA). All tests were two-tailed test, and the statistical significance level was < 0.05.

Results

Study Population Flow

Figure 1 illustrates the overall flow of the study population. Adult patients aged 18 years of age or older, who visited the ED due to trauma from October 2015 to December 2020, were eligible for the study. Of the 38,691 adult injured patients visiting the ED, 135 were excluded because of missing data, leaving 38,556 subjects (37,746 in the non-farmer group and 810 in the farmer group) for unmatched sample analysis and propensity score matching. After 1-to-1 nearest-neighbor propensity score matching, the 1,620 matched subjects were equally classified into two groups, namely, non-farmers and farmers.

Baseline Demographics

Table 1 provides a comparison of the baseline demographics between the farmer and non-farmer groups before and after propensity score matching. In the unmatched sample, there were significant differences in the patients’ demographics prior to an injury event between the two groups (farmer vs. non-farmer) in terms of sex (37.3% female vs. 44.3% female), age (61.1 ± 13.2 vs. 47.6 ± 18.8 years), inhabitant (1.6% visitors vs. 16.5% visitors), insurance type (4.8% auto insurance vs. 18.6% auto insurance), and distribution in the year. In addition, we found statistically significant differences in demographics related to the injury, such as alcohol-relatedness of the injury, EMS usage, AVPU mental status,
Glasgow Coma Scale (GCS) score, systolic blood pressure < 90 mmHg, and disposition (P < 0.05).

After propensity score matching, several of the these differing baseline demographics (age, sex, inhabitant, insurance type, and year of injury) were balanced in the matched sample. However, after matching, there were still significant differences in alcohol-related injury and disposition, but no significant differences in EMS usage, AVPU mental status, GCS score, and systolic blood pressure < than 90 mmHg between farmers and non-farmers.

**Injury Characteristics**

The injury characteristics before and after matching between the farmer and non-farmer groups are presented in Table 2.

In both the unmatched and propensity score-matched samples, there was a clear difference in most of the injury characteristics between the two groups: even after matching, the trend for group differences in the distribution of injury characteristics persisted and was more pronounced. In particular, injured patients in the farmer group were more likely to have an accidental injury, cut or penetrating injury as the injury mechanism, injury occurring during paid work activity, injury occurring in an outdoor workspace, and a temporal incidence pattern involving non-winter, weekend, and daytime injuries than the non-farmer group. On the other hand, injured patients in the non-farmer group were more likely to involve intentional violent injury, fall/slip as the mechanism of injury, injury during vital or unpaid work activity, injury occurring indoors in the home/residence as the place of injury, and a temporal incidence pattern involving winter, weekday, and other than daytime injuries than the farmer group.

**Injury Severity and Clinical Outcomes**

The descriptive statistics for injury severity and clinical outcomes are presented in Table 3, while the odds ratios (ORs) for clinical outcomes in the farmer group as compared with the non-farmer group are summarized in Table 4.

Injury severity (RTS and ISS) and clinical outcomes (in-hospital mortality, ICU admission, and surgery) were significantly different between the two groups in the unmatched sample. Injured patients in the farmer group had a higher injury severity, greater mortality within 14 days, and a greater prevalence of ICU admission and more frequently required surgery than those in the non-farmer group. However, the
differences in injury severity and clinical outcomes were not significant between the groups, except for
the indication for surgery after propensity score matching. In the matched sample, injured patients in
the farmer group had a greater prevalence of surgery than those in the non-farmer group.

The results of multivariate logistic regression analysis adjusted for potential confounders (age, sex,
inhabitant, insurance type, and year of injury) in the unmatched sample, and the results of univariate
logistic regression analysis in the matched sample for primary and secondary outcomes are summarized
in Table 4.

In multivariate logistic regression analysis of the unmatched dataset (N=38,556), farmers showed a
higher likelihood of ICU admission (adjusted OR: 1.752, 95% CI: 1.205 to 2.547, p=0.003) and higher
odds of undergoing surgery overall (adjusted OR: 1.870, 95% CI: 1.569 to 2.229, p<0.001), within 24
hours (adjusted OR: 3.025, 95% CI: 2.133 to 4.290, p<0.001), within 48 hours (adjusted OR: 2.323, 95%
CI: 1.708 to 3.157, p<0.001), and within 72 hours (adjusted OR: 2.086, 95% CI: 1.578 to 2.757, p<0.001)
compared to non-farmers. However, there was no significant difference in overall mortality (adjusted
OR: 1.358, 95% CI: 0.592 to 3.115, p=0.470), mortality ≤ 7 days (adjusted OR: 2.258, 95% CI: 0.969
to 5.259, p=0.059), and mortality ≤ 14 days (adjusted OR: 1.792, 95% CI: 0.775 to 4.140, p=0.172)
between the two groups.

In univariate logistic regression analysis using the propensity score-matched sample (N=1,620), there
was no significant difference in overall mortality (OR: 1.000, 95% CI: 0.321 to 3.114, p=1.000),
mortality ≤ 7 days (OR: 3.015, 95% CI: 0.607 to 14.982, p=0.177), mortality ≤ 14 days (OR: 2.007, 95%
CI: 0.500 to 8.054, p=0.326), and ICU admission (OR: 1.425, 95% CI: 0.818 to 2.484, p=0.211) between
farmers and non-farmers. However, farmers still showed higher odds of undergoing surgery overall (OR:
1.786, 95% CI: 1.377 to 2.317, p<0.001), within 24 hours (OR: 2.609, 95% CI: 1.423 to 4.781, p=0.002),
within 48 hours (OR: 1.759, 95% CI: 1.092 to 2.834, p=0.020), and within 72 hours (OR: 1.708, 95%
CI: 1.109 to 2.629, p=0.015) compared to non-farmers.

**Discussion**

We established the prospective ED-AgISS to compare the characteristics and outcomes of injuries in
agricultural workers compared to non-agricultural workers in a clinical setting at ED. In unmatched
sample, multivariate logistic regression analysis revealed mortality were not significantly different between the farmer and non-farmer groups, whereas higher adjusted ORs for farmer group for ICU admission and surgery. After propensity score matching, differences in ICU admission and mortality were not significantly different between the farmer and non-farmer groups, whereas injured patients in the farmer group more frequently required surgery than those in the non-farmer group.

Limited information is available about the clinical aspects and outcomes of non-fatal injuries in agricultural workers, because obtaining comprehensive data on non-fatal injury events is more complex than obtaining data on fatal injuries [24]. Thus, the burden of injuries in agricultural workers on the ED is not well quantified.

South Korea's proportion of injuries in agricultural workers at the ED over a 4-month period was 6.3%, based on a pilot study for developing an ED-based occupational injury surveillance system [25]. A descriptive study in North Carolina reported that an average of 459 farm injury cases occurred annually from 2008 to 2012, with little yearly variation, based on syndromic surveillance data gathered by the ED [15]. In our study, of all adult patients visiting the ED, 810 injured patients were engaged in agriculture, and the overall proportion of agricultural injuries was 2.1% (range: 1.5%–3.1%) during the study period. The burden of injuries in agricultural workers reported in other studies was higher than in our study (an average of 135 cases annually and an overall proportion of 2.1%). However, these differences may be due to geographic variations and the extent of the surveillance system.

Of our 810 injured agricultural workers visiting the ED, 508 (62.7%) were males, and the mean age was 61.1 ± 13.2 years. Several injury characteristics between farmer and non-farmer groups were different in the unmatched sample. Injuries in agricultural workers compared to non-agricultural workers mainly occurred outdoors (90.6% vs. 57.2%) during paid work (90.0% vs. 14.4%), due to unintentional accidents (96.2% vs. 92.2%), and the most common location was the workspace (65.4% vs. 8.6%). The major injury mechanisms were fall/slip (26.4% vs. 28.4%) and cut/penetrating injuries (20.9% vs. 12.3%), rather than motor vehicle collisions (10.3% vs. 22.5%). None of these individuals were covered by industrial insurance.

These results are consistent with previous findings that evaluated the characteristics and associated
factors of agricultural injuries: a higher proportion of older individuals, more males than females, low
coverage of worker compensation, more accidental than intentional injuries, major injury mechanisms
involving lacerations and sprain/strain, injuries occurring in the farm field, during paid work, and with
time variation in terms of season, days of the week, and day time \[10,12,16,26,27]\).

However, most previous studies have evaluated these results only in agriculturally engaged populations,
but our study could provide the detailed injury epidemiology of relative occupational-associated
differences in comparison with non-agricultural workers.

We also found that several baseline demographics of injured patients were significantly different
between farmer and non-farmer groups in the unmatched sample: sex, age, inhabitant, insurance type,
distribution in the year, alcohol-relatedness, EMS usage, AVPU mental status, GCS score, systolic
blood pressure < 90 mmHg, and disposition (all \( P < 0.05 \)). Among these, five patient demographic
differences (age, sex, inhabitant, insurance type, and year of injury) can be considered unique host
factors prior to the injury event.

Because of concerns about the difficult-to-adjust structural confounding associated with the
observational study design and the relatively small sample size of the farmer's group, our analysis using
a traditional regression model or covariate adjustment approach was less robust in handling endogeneity
bias, and made it more challenging to assess the impact of occupation (farmers vs. non-farmers) on
injury epidemiology and clinical outcomes. Therefore, we adopted a propensity score-matching
approach to balance the participants’ baseline demographics and the sample size between the two groups
\[23\].

Table 5 shows the extent of the balance between the two samples before and after matching. For each
matching variable, the absolute standardized mean difference was less than 0.05, indicating that
covariates were balance in the matched samples. There was almost a 94.8% (range: 86.8–98.5%)
reduction in these covariates' standardized mean differences after matching \[22\]. Figure 2 shows the
extent of covariate imbalance in standardized percentage differences using dot charts.

We also calculated the overall measures of covariate imbalance before and after propensity score
matching. Rubins' B (the absolute standardized difference of the means) and Rubins' R (the ratio of
treated to non-treated variances of the propensity score index) were 7.4 and 1.28, respectively, in the matched sample, which was considered to indicate sufficient balance [23].

Only alcohol-related injury and ED disposition were significantly different among the demographics after propensity score matching, while EMS usage, AVPU mental status, GCS score, and systolic blood pressure < 90 mmHg were not significantly different after matching. A possible explanation for these results might be that group differences in demographics at the time of injury were associated with host factors that could not modify the characteristics of farm workers as compared to non-farmers. However, in terms of injury characteristics, one interesting finding is that the group differences in the distribution of most injury characteristics remained statistically significant in both the unmatched and matched samples. These group differences in injury characteristics that persisted after achieving a similar distribution of host factors across farmers and non-farmers might be associated with the nature of the occupational influences.

Similar to previous studies, the results of this study showed that the farmer group had significantly higher rates of ICU admission, surgery, and mortality than did the non-farmer group [28–31]. However, multivariate logistic regression analysis in the unmatched sample, adjusted for potential confounders (age, sex, inhabitant, insurance type, and year of injury), showed that the adjusted OR for mortality was not statistically significant. Furthermore, univariate logistic regression analysis using the propensity score-matched sample to compare clinical outcomes showed that only the OR for the prevalence of surgery was significant.

These findings are somewhat surprising given that other studies have reported high mortality and morbidity rates in agricultural workers [4,7,10,17,25,28–31]. A potential reason for this discrepancy could be the study design and setting. Our participants were recruited from among injured patients who visited the ED, using a prospective registry. Several previous studies evaluating the mortality and morbidity of injuries in agricultural workers used data collection methods that differed from ours. They used data sources, such as industrial compensation records, insurance claims data, and working condition surveys [17,25,32–35]. Therefore, the participants in our study might have been mainly non-fatal injuries visiting the ED and our study may have excluded individuals with fatal injuries that had
already died in the prehospital phase. Another possible reason could be our statistical analysis method. We used a multivariate logistic model as well as a propensity score-matching to control for the effect of host confounders on clinical outcomes. Therefore, our results regarding clinical outcomes need to be interpreted with caution and should be limited to non-fatal injured patients visiting the ED, rather than being extrapolated to all injuries in agricultural workers.

These findings suggest that the targets for the prevention of injuries in agricultural workers might differ, depending on the timing of the injury. Primary prevention may be an important prehospital phase intervention to avoid fatal injuries in agricultural workers, such as by providing roll-over protection structures and seatbelts on tractors [36]. Additionally, preventive efforts to reduce the morbidity of non-fatal injuries in agricultural workers need to be prioritized in the hospital phase. Thus, ED physicians should understand the special considerations for managing acute injuries of agricultural workers, including the triad of Ts: excessive time until treatment, excessive trash or wound contamination, and excessive trauma to tissues and organs [37]. Sufficient human resources to perform operations, such as reconstruction, attachment, and amputation, are also essential because of high likelihood of surgery.

There were several limitations in our study that require attention. First, the major limitation of our study population was that they were not representative samples of the target populations. Thus, results estimates must be interpreted cautiously, and should not be extrapolated all severity of work-related agricultural injury beyond non-fatally injured patients in agricultural workers visiting the ED. Second, 135 participants were excluded from the 38,691 eligible participants because of missing essential variables. Although the size of the excluded sample was relatively minimal, at 0.3%, the proportion in the farmer group was significantly higher than that in the non-farmer group (2.8% vs. 0.3%, P < 0.001). Therefore, the possibility of bias, other than systematic missing data, cannot be excluded. Third, the regional generalizability of our study is weak, because our study population was obtained from a small subset of only one province. In addition, injuries in agricultural workers were strongly associated with environmental and safety cultures at the farm and individual levels. Therefore, the generalizability of these results to other regions may be limited.
In summary, our study identified differences in injury characteristics between agricultural and non-agricultural workers, with a significantly higher prevalence of surgery among agricultural workers, and no significant differences in mortality across both matched and unmatched sample analyses. Our findings suggest the importance of tailoring the target and strategy of injury prevention for agricultural workers by emphasizing primary prevention in the prehospital phase to avoid fatal injuries, while prioritizing preventive efforts to reduce morbidity in non-fatal injuries in the hospital phase.
References


**FIGURE 1.** Study population flow

- Total Injured Patients visiting ED (Oct 1, 2015 to Dec 31, 2020) N=54,263
  - 15,572 patients excluded due to <18 years old
- Adult (≥ 18 years) Injured Patients visiting ED N=38,691
  - Exclusions (n=135)
    - Undetermined for mortality (n=14)
    - Undetermined for surgery (n=7)
    - Undetermined for injury severity (n=116)
- 38,556 Injured Patients
  - Non-Farmers N=37,746
  - Farmers N=810
  - Unmatched Sample N=38,556
    - 1:1 Nearest Neighbor Propensity Score Matching
  - Non-Farmers N=810
  - Farmers N=810
  - Matched Sample N=1,620
FIGURE 2. The extent of covariate imbalance before and after propensity score matching