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# Bootstrapping estimation of the workload ratio by an occupational group of human healthcare resources of a Hospital in Ayacucho, Peru

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**ABSTRACT**

**The analysis of the workloads present in the way of working is a promising way to guide the provision of care to users and thus, improve the quality of access to health services. On the hypothesis that there is no relationship between knowledge and acceptance of the estimate of the gap in care human resources in a Regional Hospital in Ayacucho and the wide demand for human resources in health in Peru it is necessary to estimate the gap in healthcare human resources of a hospital in the Ayacucho region. The objective of this research is to estimate the gap in care human resources, expressed in the ratio of workloads per occupational group of a Regional Hospital in Ayacucho by bootstrapping. The measurement of the RHUS workload ratio was carried out individually for each occupational group. The sample was made up of n = 744 healthcare personnel. The estimation of the workload ratio was carried out by bootstrapping, considering the non-parametric tests of Kruskal-Wallis and Mann-Whitney U by occupational group of the healthcare human resources. The results showed an asymmetric distribution of the workload ratio, influenced by the presence of an occupational group of Medical Professionals, which turned out to be the most numerous and the one with the greatest deficiencies. There were no significant differences between the three occupational groups of human resources in health. The bootstrapping estimation suggested considering a sample size n = 50 as the threshold between large and small samples in this study. The robustness of the bootstrapping estimators was verified in the context of asymmetric distributions, and especially for estimates of the workload ratio by occupations group of human resources in health**

**Keywords: gap, deficiencies, Medical Professionals, asymmetric distributions, non-parametric.**

## INTRODUCTION

Guaranteeing universal access is of utmost importance for human life and represents a significant challenge for countries and professionals in this area (Buss, 2014; Frenk, 2015). It is necessary to achieve universal access to health to address who does the work, how it is carried out, and under what conditions in different historical and social contexts. In this way, the workload is the amount of time assigned to each RHUS to develop assistance, administrative and training activities. In general, its measurement is carried out in annual periods and is expressed in hours as a unit of time. The loads interact with each other and the body of who does the work; they do not act in isolation. In contrast, in combination with others, and determine the condition in which the worker faces the global logic of the work process (Laurell and Noriega, 1989).

Countries have been planning for human resources for health for a long time. In parallel, demand has grown for tools to facilitate that planning, including devices that can assist with applying objective and scientific methodologies to estimate health workforce requirements. Initially, it was thought that assessing the required numbers accurately for a service industry such as health could present insurmountable difficulties. But as progress has been made in quantifying the services needed, it has become possible to quantify the quantity and quality of health workers needed. The challenge of making the tools more user-friendly is increasingly being met (World Health Organization, 2016). Therefore, the analysis of the workloads present in working is a promising way to guide the provision of care to users and improve access to health services (Pires *et al*., 2016). Hence, the calculation of the gap in human resources in health (RHUS) has as a product quantifying the difference between the need and availability of RHUS for healthcare services that allow. However, within their effective working hours, to meet the effective demand for medical procedures of the Essential Health Insurance Plan (PEAS) and develop other assistance activities not considered in the PEAS and the administrative and training activities that are part of their workload at the first level of care (MINSA, 2014).

Estimating human resource gaps in a tertiary hospital will serve to achieve the necessary resources for the proper functioning of the health center. From the hypothesis, there is no relationship between knowledge and acceptance of the estimate of the gap in care human resources in a Regional Hospital in Ayacucho. Therefore, the broad demand for human resources in Peru and especially at the regional level is necessary to estimate the gap in human healthcare resources of a hospital with the maximum resolution capacity within the Ayacucho region. In this sense, this research aims to evaluate the gap in care human resources, expressed in the ratio of workloads per occupational group of a Regional Hospital in Ayacucho by bootstrapping.

## MATERIAL AND METHODS

### The ratio of the workload of human resources in health (RHUS)

The workload ratio measures the percentage of availability to the estimated need for RHUS. The measurement of the RHUS workload ratio was carried out individually for each occupational group and involved the development of the following expression (for details, see MINSA, 2014):

$$(RRHUS)_i = {}^{D_i}/_{N_i} \quad \text{for } i = 1,2,3$$

where:
$(RRHUS)_i$: workload ratio of healthcare RHUS.
$D_i$: availability of healthcare RHUS.
$N_i$: the need for healthcare RHUS.
The values obtained by each occupational group account for the existing gap in the analyzed health network.
The interpretation of the estimate of the Workload Ratio for each occupational group gives us the following types of results:
**Ratio = 1**; Health establishment of the new infrastructure of the Regional Hospital of Ayacucho with the balanced endowment of the analyzed occupational group.
**Ratio < 1**; Health establishment with an insufficient staff of the analyzed occupational group. When the balance is further away from unity, the greater the deficit is evidenced.
**Ratio > 1**; Health establishment with sufficient staffing for the occupational group analyzed. When the ratio is further from unity, the greater will be the excess evidenced.

The sample was made up of $n$ = 744 healthcare personnel, named in the 276 labor regime and hired in the CAS modality and third parties, 10 department heads who participated in the estimation and validation of the gap in human resources for healthcare in the Ministry of Health in the city of Lima and that they met the selection criteria.

### Statistical analysis

### Bootstrapping estimation

The estimation of the workload ratio was carried out by bootstrapping, considering the non-parametric tests of Kruskal-Wallis and Mann-Whitney $U$ by an occupational group of the human healthcare resources of a Hospital in Ayacucho, Peru. Thus, in addition to the maximum likelihood estimators of the parameters of the nonlinear models considered in this investigation, the estimation was performed using the bootstrap method proposed by Efron (1979), which is one of the simplest methods used to obtain an estimator of a parameter $\beta = \beta(P)$ where $P$ is the postulated statistical model. Alonso (2001) presents the bootstrap method in a general situation:
Let be $Z = (Z_1, Z_2, \ldots, Z_n)$ a data set generated by the statistical model $P$, and let be $T(Z)$ the statistic whose distribution L($T$ ; $P$) we wish to estimate. The bootstrap method proposes as an estimator of L($T$ ; $P$) the distribution L*($T$*; $n$ $P$ˆ ) of the statistic $T$* =$T$ ($Z$*), where $Z$* is a data set generated by the estimated model $\hat{P}_n$. Note that if $\hat{P}_n = P$, then the distributions L($T$;$P$) and $L^*(T^*;\ \hat{P}_n)$ coincide. Then if we have a good estimator of $P$, it is logical to suppose that $L^*(T^*;\ \hat{P}_n)$ it will approach L($T$ ; $P$).
The models described above, their estimators (*bootstrap*) and the statistical test were determined in the R environment, using the "drc" package and the "boot" package (R Core Team (2020), for details, see Appendixes 1 and 2.

### Comparison of the workload ratio

The workload ratio was compared by an occupational group of the human healthcare resources of a Hospital in Ayacucho, Peru using the Kruskal–Wallis test by ranks, Kruskal–Wallis H test (Kruskal and Wallis, 1952a); named after William Kruskal and W. Allen Wallis, or one-way ANOVA on ranks is a non-parametric method for testing whether samples originate from the same distribution. It is used for comparing two or more independent samples of equal or different sample sizes (Kruskal and Wallis, 1952b; Corder and Foreman,2009 and Siegel and Castellan, 1988). It extends the Mann–Whitney *U* test, which is used for comparing only two groups. The parametric equivalent of the Kruskal–Wallis test is the one-way analysis of variance (ANOVA).
A significant Kruskal–Wallis test indicates that at least one sample stochastically dominates one other sample. The test does not identify where this stochastic dominance occurs or how many groups of groups stochastic dominance obtain. For analyzing the specific sample pairs for stochastic dominance, Dunn's test (Dunn, 1964) pairwise Mann–Whitney tests with Bonferroni correction (Conover and Iman, 1979a) or the more powerful but less well known Conover–Iman test (Conover and Iman, 1979b) are sometimes used.

## RESULTS AND DISCUSSION

Figures 1 generally show an asymmetric distribution of the workload ratio in three occupational groups of the human healthcare resources of a Hospital in Ayacucho, Peru. Likewise, the box plots in Figure 2 suggest the presence of an occupational group of Medical Professionals with a tendency to be asymmetrically distributed that can considerably influence the distribution of the three groups (see Figure 1). This is evidenced in the distribution of the workload ratio by an occupational group of human healthcare resources shown in Figure 3.

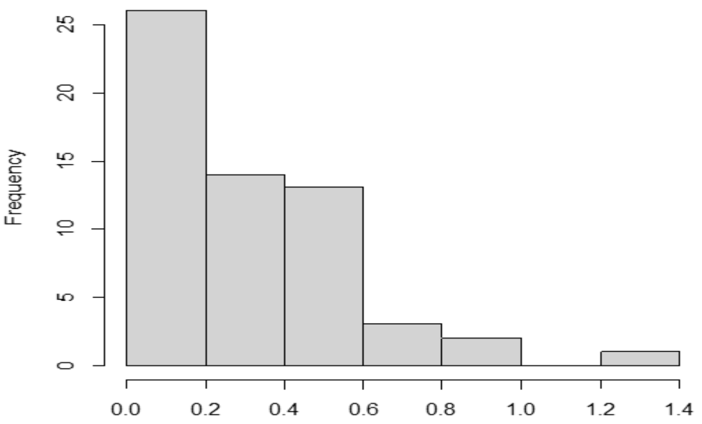


**Figure 1:** Distribution of the workload ratio in three occupational groups of human healthcare resources of a Hospital in Ayacucho, Peru.

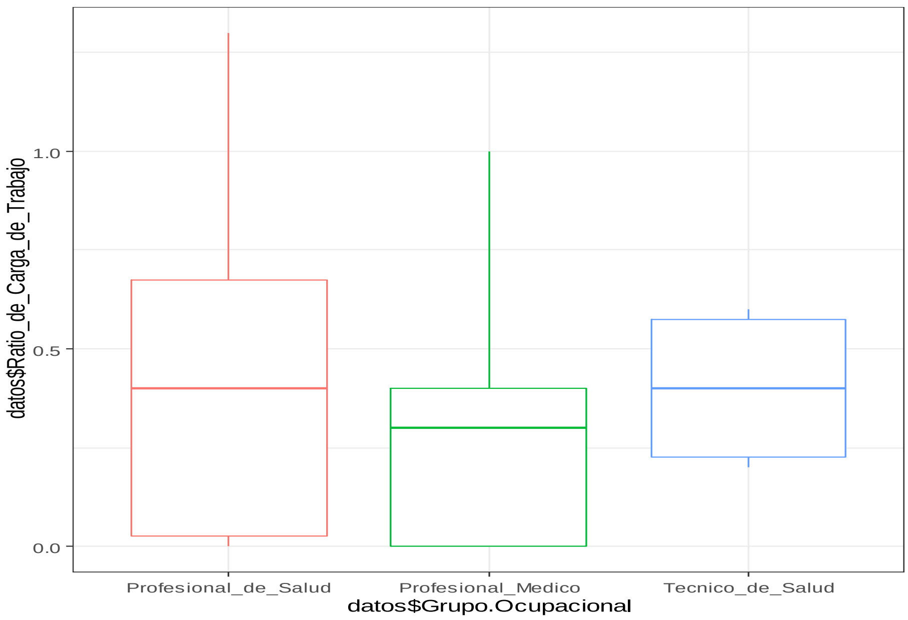


**Figure 2:** Box-plot of the workload ratio of three occupational groups of human healthcare resources of a Hospital in Ayacucho, Peru.

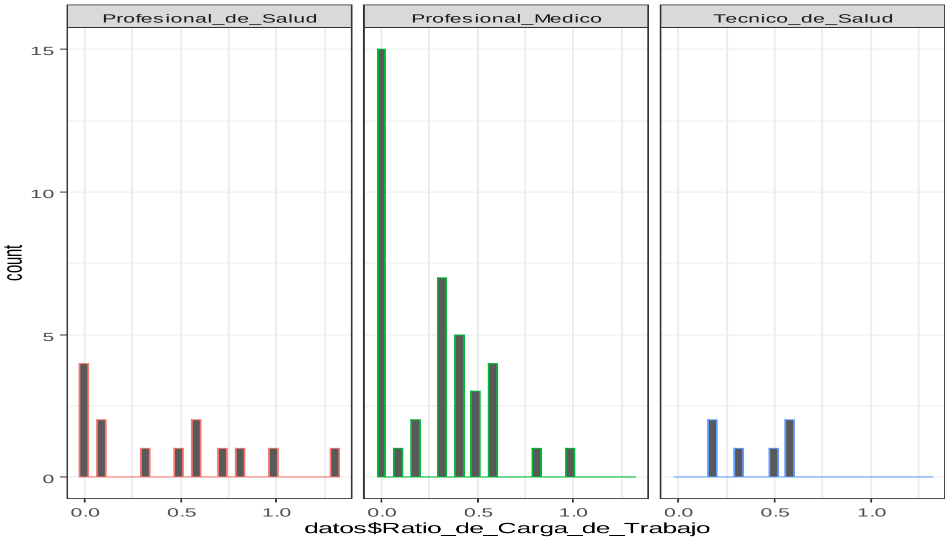


Figure 3: Distribution of the workload ratio by an occupational group of human healthcare resources of a Hospital in Ayacucho, Peru.

In this sense, Tables 1-3 show that the median for the workload ratio (*RRHUS*) of the group of Medical Professionals (*RRHUS* = 0.3) is lower than that of Health Professionals and Health Technicians (*RRHUS* = 0.4), respectively, being the group of Medical Professionals, the most numerous and consequently the one that shows the greatest deficiencies. According to (MINSA 2014), the analysis of the results of the workload ratio determines the gaps in proportional terms both of the deficit or excess found for each occupational group. Thus, valuable information is obtained as a starting point to start the process of strategic provision of RHUS for the Hospital's care services. The asymmetry of the distribution indicated above suggests an exhaustive analysis from a non-parametric approach.

**Table 1:** Estimating the workload ratio by occupational group (Medical professional) of a Hospital's healthcare human resources in Ayacucho, Peru.

| Occupational group | RRHUS | Interpretation | Occupational group | RRHUS | Interpretation |
|---|---|---|---|---|---|
| Surgeon | 0 | ND | Nephrology | 0 | D |
| Family Medicine | 0 | ND | Neonatology | 0 | D |
| Internal Medicine | 0.4 | D | Endocrinology | 0.3 | D |
| Pediatrics | 0.3 | D | Geriatrics | 0 | D |
| Cardiology | 0.2 | D | Dermatology | 0 | D |
| Neurology | 1 | ND | Infectology | 0 | D |
| Pneumology | 0.3 | D | Obstetrics Gynecology | 0.4 | D |
| Rheumatology | 0.3 | D | General Surgery | 0.5 | D |
| Psychiatry | 0.4 | D | Head and Neck Surgery | 0 | D |
| Physical Medicine and Rehabilitation | 0.3 | D | Thorax and Cardiovascular Surgery | 0 | D |
| Radiology | 0.1 | D | Oncologic surgery | 0 | ND |
| Clinical pathology | 0.4 | D | Pediatric Surgery | 0.6 | D |
| Pathological anatomy | 0.3 | D | Plastic surgery | 0 | D |
| Medical Oncology | 0 | D | Neurosurgery | 0.8 | D |
| Intensive medicine | 0.3 | D | Urology | 0.5 | D |
| Gastroenterology | 0.6 | D | Otorhinolaryngology | 0.5 | D |
| Emergencies and Disasters | 0.2 | D | Ophthalmology | 0.4 | D |
| Clinical Hematology | 0 | D | Traumatology and orthopedics | 0.6 | D |
| Nuclear medicine | 0 | ND | Anesthesiologist | 0.6 | D |
| Radiotherapy | 0 | ND | | | |
| Median RRHUS | 0.3 | | | | |

*D = deficit, ND: no deficit.*

**Table 2:** Estimation of the workload ratio by occupational group (Health professional) of the human healthcare resources of a Hospital in Ayacucho, Peru.

| **Occupational group** | **RRHUS** | **Interpretation** |
|---|---|---|
| Dental surgeon | 0.6 | D |
| Nurse | 0.5 | D |
| Psychologist | 1 | ND |
| Obstetrician | 0.8 | D |
| Medical Technologist - Rehabilitation Area | 0.1 | D |
| Medical Technologist - Occupational Therapy Area | 0 | D |
| Medical Technologist - Language Therapy Area | 0 | D |
| Hearing and Language Specialist | 0 | ND |
| Medical Technologist - Radiology Area | 0.1 | D |
| Medical Technologist -Laboratory / Biologist Area | 0.7 | D |
| Optometry Medical Technologist | 0 | D |
| Nutritionist | 0.3 | D |
| Social worker | 1.3 | ND |
| Pharmaceutical chemist | 0.6 | D |
| Median RRHUS | 0.4 | |

*D = deficit, ND: no deficit.*

**Table 3:** Estimating the workload ratio by occupational group (Health technician) of the human healthcare resources of a Hospital in Ayacucho, Peru.

| **Occupational group** | **RRHUS** | **Interpretation** |
|---|---|---|
| Nursing Assistance Technician | 0.6 | D |
| Nutrition Assistance Technician | 0.5 | D |
| Assistance Technician in Radiology | 1 | ND |
| Laboratory Assistance Technician | 0.8 | D |
| Assistance Technician in Physiotherapy | 0.1 | D |
| Assistance Technician in Pharmacy | 0 | D |
| Median RRHUS | 0.4 | |

*D = deficit, ND: no deficit*

Table 4 presents bootstrapping estimates of the effect of the occupational group of human healthcare resources of a Hospital in Ayacucho, Peru on the workload ratio, considering the non-parametric Kruskal-Wallis test. These results show that as the number of bootstrap replicas increases ($n > 50$) the P-value of the test statistic tends to stabilize around P = .21, which suggests that there are no significant differences (P >.05) regarding the distribution of the workload ratio by an occupational group of human healthcare resources of a Hospital in Ayacucho, Peru. However, the asymmetry observed in the distribution of the occupational group of Medical professionals (see Figures 2 and 3) suggests a more exhaustive study involving more complex models for the analysis of asymmetric data, such as; generalized additive models for location, scale and shape (GAMLSS) which are semi-parametric regression type models. They are parametric. They require a parametric distribution assumption for the response variable and "semi" in the sense that the modelling of the distribution parameters, as functions of explanatory variables, may involve using non-parametric smoothing functions. GAMLSS were introduced by Rigby and Stasinopoulos (2005) and Akantziliotou *et al*. (2002) as a way of overcoming some of the limitations associated with the popular generalized linear models, GLM, and generalized additive models, GAM (see Nelder and Wedderburn (1972); Hastie and Tibshirani (1990), respectively).

**Table 4:** Bootstrapping estimate of the *P*-value associated with the Kruskall-Wallis test statistic compares the workload ratio by an occupational group of human healthcare resources of a Hospital in Ayacucho, Peru.

| Bootstrap replicates | Kruskal-Wallis statistic | *P*-value |
|---|---|---|
| 10 | 3.921165 | .2000 |
| 30 | 4.477475 | .3333 |
| 50 | 3.961993 | .2600 |
| 100 | 3.577957 | .2000 |
| 200 | 3.814276 | .2000 |
| 500 | 4.016856 | .2140 |
| 1000 | 4.03821 | .2190 |
| 2000 | 4.028809 | .2225 |
| 5000 | 4.067125 | .2236 |
| 10000 | 4.003616 | .2168 |

On the other hand, Table 5 shows the comparison of the workload ratio by an occupational group of the human healthcare resources of a Hospital in Ayacucho, Peru using the Mann–Whitney *U* test. It is observed that there are no significant differences ($P > .05$) regarding the distribution of the workload ratio by an occupational group of the human healthcare resources of a Hospital in Ayacucho, Peru, which coincides with what was obtained in Table 4 regarding the bootstrapping estimate of the effect of an occupational group of human healthcare resources.

**Table 5:** Comparison of the workload ratio by an occupational group of the human healthcare resources of a Hospital in Ayacucho, Peru using the Mann–Whitney *U* statistic.

| Occupational group / Occupational group | Health professional | Medical professional |
|---|---|---|
| Medical professional | .53 | - |
| Health technician | .90 | .53 |

In Figure 4 and Table 1 it is observed how the estimate of the P-value tends to stabilize for several bootstraps replicates $n > 50$, which suggests considering the sample size $n = 50$ as the thresholds between large and small samples in this study of the workload ratio by an occupational group of the human healthcare resources of a Hospital in Ayacucho, Peru. Likewise, Figure 5 shows the bootstrapping distribution of the Kruskal-Wallis test statistic, which is distributed as a chi-square, which verifies the robustness of the bootstrapping estimators in the context of asymmetric distributions, and especially for estimates of the Workload ratio by an occupational group of human healthcare resources of a Hospital in Ayacucho, Peru. Pattengale *et al*. (2010) suggest a criterion of 100 to 500 replicates (although the more conservative standard can continue for several thousand replicates).

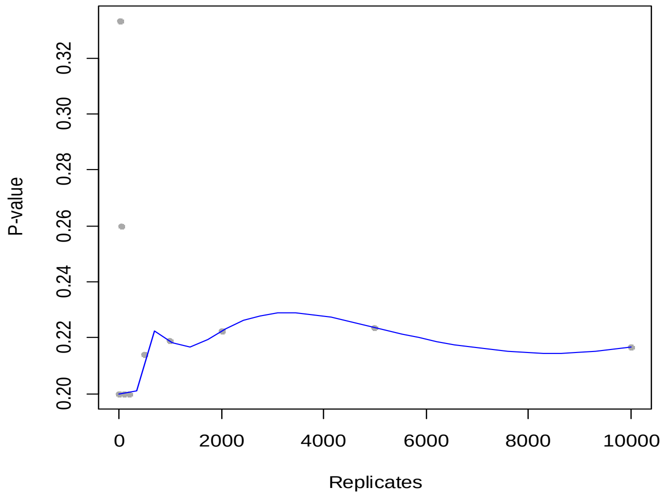


**Figure 4:** Bootstrapping estimate of the *P*-value associated with the Kruskall-Wallis test statistic compares the workload ratio by an occupational group of human healthcare resources of a Hospital in Ayacucho, Peru.

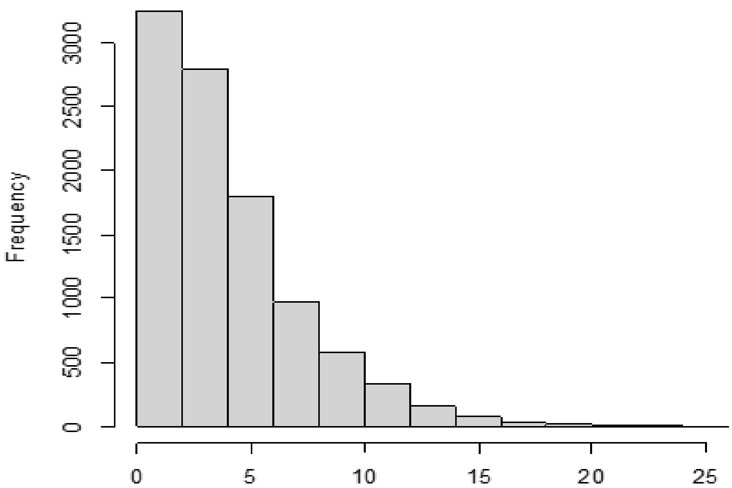


**Figure 5:** Bootstrapping distribution of the Kruskal-Wallis test statistic to compare the workload ratio by an occupational group of human healthcare resources of a Hospital in Ayacucho, Peru.

Finally, the process of human resources for health planning involves determining and putting in place strategies to obtaining the required number of health workforce with the right skills and competency; and their appropriate deployment to deliver timely and affordable services that address population health needs (Hornby, 1980; Sharman et al., 2014). Health workforce forecasting is one of the initial elements of broader human resources for health planning (Kolehmainen, 1993). It encompasses taking stock of the available health workforce and estimating the current and future health workforce needed and comparing it with the expected supply. This helps to establish demand and supply gaps (labor market gaps) or current need-availability gaps (López et al., 2015; Kolehmainen, 1993)

## CONCLUSIONS

Asymmetric distribution of the workload ratio was evidenced in three occupational groups of human health resources, influenced by an occupational group of Medical Professionals, which turned out to be the most numerous and consequently the one with the most significant deficiencies. The bootstrapping estimate of the effect of the occupational group of human resources in health on the workload ratio showed no significant differences between the three occupational groups of human resources in a hospital's health in Ayacucho, Peru. The bootstrapping estimation suggested considering a sample size $n$ = 50 as the threshold between large and small samples in this study. The robustness of the bootstrapping estimators was verified in the context of asymmetric distributions, and especially for estimates of the workload ratio by occupations group of human resources in health. Finally, the asymmetry observed in the distribution of the workload ratio by an occupational group of human resources in health suggests a more exhaustive study that involves more complex models for the analysis of asymmetric data, such as; Generalized Additive Models for Location, Scale and Shape (GAMLSS) that are semi-parametric regression models.

## ETHICAL APPROVAL

As per international standards or university standards, ethical approval has been collected and preserved by the authors.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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## APENDIX

**Apendix 1.** R code for the bootstrapping estimate of the P-value associated with the Kruskall-Wallis test statistic to compare the workload ratio by occupational group of healthcare human resources of a Hospital in Ayacucho, Peru.

```
datos
hist(datos$Ratio_de_Carga_de_Trabajo)
ratio_PM<-datos[1:n_PM,Ratio_de Carga_de_Trabajo]
ratio_PM
ratio_PS<-datos[n_PM+1:n_PS, Ratio_de Carga_de_Trabajo]
ratio_TS<-datos[n_PS+1:n, Ratio_de Carga_de_Trabajo]
n_PM<-length(ratio_PM)
n_PS<-length(ratio_PS)
n_TS<-length(ratio_TS)
R = rep
Fstar = numeric(R)
for (i in 1:R) {
group_PM = runif(n_PM,min(ratio_PM),max(ratio_PM))
group_PS = runif(n_PS,min(ratio_PS),max(ratio_PS))
group_TS = runif(n_TS,min(ratio_TS),max(ratio_TS))
simDT=c(group_PM,group_PS,group_TS)
simgrupo = datos$Grupo.Ocupacional
simdata = data.frame(simDT,simgrupo)
kruskal.test(simDT~simgrupo,data=simdata)$p.value<=0.05->r
Fstar[i]=r
Fstar[i]=kruskal.test(simDT~simgrupo,data=simdata)$statistic
}
sum(Fstar)/R
```

**Apendix 2.** R code for the comparison of the workload ratio by occupational group of healthcare human resources of a Hospital in Ayacucho, Peru using the Mann–Whitney *U* statistic.

```
datos
hist(datos$Ratio_de_Carga_de_Trabajo)
ratio_PM<-datos[1:n_PM,Ratio_de Carga_de_Trabajo]
ratio_PM
ratio_PS<-datos[n_PM+1:n_PS, Ratio_de Carga_de_Trabajo]
ratio_TS<-datos[n_PS+1:n, Ratio_de Carga_de_Trabajo]
n_PM<-length(ratio_PM)
n_PS<-length(ratio_PS)
n_TS<-length(ratio_TS)
R = rep
Fstar = numeric(R)
for (i in 1:R) {
group_PM = runif(n_PM,min(ratio_PM),max(ratio_PM))
group_PS = runif(n_PS,min(ratio_PS),max(ratio_PS))
group_TS = runif(n_TS,min(ratio_TS),max(ratio_TS))
simDT=c(group_PM,group_PS,group_TS)
```

```
simgrupo = datos$Grupo.Ocupacional
simdata = data.frame(simDT,simgrupo)
pairwise.wilcox.test(x = simDT, g = simgrupo, p.adjust.method = "holm" )
head(pairwise.wilcox.test(x = simDT, g = simgrupo, p.adjust.method = "holm" ))$p.value
PM_PS<-head(pairwise.wilcox.test(x = simDT, g = simgrupo, p.adjust.method = "holm" ))$p.value[1,1]
TS_PS<-head(pairwise.wilcox.test(x = simDT, g = simgrupo, p.adjust.method = "holm" ))$p.value[2,1]
TS_PM<-head(pairwise.wilcox.test(x = simDT, g = simgrupo, p.adjust.method = "holm" ))$p.value[2,2]
PM_PS<=0.05->r1
TS_PS<=0.05->r2
TS_PM<=0.05->r3
Fc<-cbind(r1,r2,r3)
Fstar[i]=Fc
}
sum(Fstar)/R
```