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Review Article

A comprehensive review of the healthy worker effect in occupational epidemiological studies

Fahad Saad Algarni*

Department of Rehabilitation Health Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia

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***Correspondence:**
Dr. Fahad Saad Algarni,
E-mail: falgarni@ksu.edu.sa

ABSTRACT

The reduction of mortality and morbidity rates among occupational cohort studies may be attributed to the presence of the healthy worker effect (HWE). Occupational epidemiologic studies investigating worker's health are prone to the risk of having the HWE phenomenon and this special form of bias has been debated over the years. Hence, it's imperative to explore in-depth the magnitude and sources of HWE, and further, elucidate the factors that may affect HWE and strategies reducing HWE. The HWE should be considered as a mixed bias between selection and confounding bias. The validity threats due to the HWE among morbidity studies are the same as the mortality studies. The consequent reduction due to the HWE in the association between the exposure and outcome may lead to underestimating some harmful exposures in the workplace or occupational settings. Healthy hire effect and healthy worker survivor effect are the main sources of HWE. Several factors can increase or decrease the probability of HWE; therefore, the investigators should consider them among future occupational epidemiological studies. Many strategies can help in reducing the impact of HWE, but each strategy has its weaknesses and strengths. Not all strategies can be applied among all occupational epidemiological studies. Mathematical procedures still need further investigations to be validated. HWE is a consequence of inappropriate comparison groups in nature. The usage of the general population as a reference group is not an appropriate choice. By considering the HWE sources and factors and using appropriate strategies, the impact of HWE may be reduced.

Keywords: Confounding bias, Healthy worker effect, Healthy worker survivor effect, Occupational epidemiology, Selection bias

INTRODUCTION

Occupational epidemiology is 'the systematic study of illnesses and injuries that are related to the workplace environment.[1] This epidemiological sub-discipline has encountered some validity threats such as the HWE. The term HWE was defined as 'a term applied to the deficit of both morbidity and mortality ascribed to various employment-associated factors when workers and the general population were compared.[2] Moreover, others defined HWE as 'the reduction of mortality or morbidity of occupational cohorts when compared with the general population.[3]

The dictionary of epidemiology defines the HWE as the 'deviation of results or influences from the truth, or processes leading to such deviation.[4] The HWE is still a serious methodological problem among occupational epidemiologic studies, although there have been efforts by occupational epidemiologists to remove it or at least reduce it.[5]

In 1985, William Ogle reported that mortality rates depend on the difficulty of occupations. These rates were less among workers with vigorous occupations compared to workers in less vigorous occupations, or with unemployed people.[6] Firstly, healthy worker effect term

was used by McMichael et al to indicate that mortality and morbidity rates were influenced by the requirements or conditions of employers to recruit healthy individuals only. Thus, the rates of mortalities and morbidities of occupational cohorts would be less than the general population, as the active workers tended to be healthier than the unemployed or unfit people who were in the general population.[7,8] Standardized mortality ratio (SMR) close to unity (100) is used as an indication of absence or a low degree of HWE.[9] Morbidity studies involve different designs to examine different endpoints: for example, chronic diseases such as cardiovascular disease or nonmalignant respiratory disease, physiologic function such as blood pressure or pulmonary function, or musculoskeletal disorders such as carpel tunnel syndrome or back pain.[10] Thus, morbidity studies would have the same importance and face similar threats as mortality studies. However, the HWE is a potential problem that may face all occupational epidemiological studies including mortality, physiologic function, or morbidity.[10]

It is important to note that there is no special technique or method to measure the HWE bias, but it needs critical thinking and analyses for occupational epidemiology studies which usually have a potential risk of having HWE. For example, HWE bias in a previous morbidity study was observed among grain workers who were examined through pulmonary function (FEV1) in a cohort of new hires.[11] The investigators found that only one third of the new hires were still working after four years. They also observed that the annual rate of FEV1 level decreases as the duration of employment increases. The investigators also found that the rate of losing lung function was very rapid in the first two years, while this rate was slower among those workers who were still working after four years of follow-up. It is clear that by stratifying employment status (leaving and staying workers), the investigators could identify this HWE bias.

Is the HWE a selection, information or confounding bias? There is no consensus among investigators regarding the answer for this question. First, healthy workers are usually more likely to stay in the workforce more than unhealthy workers, who usually either leave the job or transfer to another job with less-exposure. In brief, this bias might be related to either health related to initial hiring, or any subsequent factors which may enforce some workers to stop working. This perspective leads to classify HWE as a selection bias.[2,3] Second, in the comparison between occupational cohorts and the general population, there might be some differences with respect to the cause of death (in mortality studies), or differences in 'methods and quality of recording the health outcomes between the two populations.[2] This perspective indicates information bias more than selection bias.[12] Finally, some employers do not allow workers to smoke during working hours and consider some personal traits like obesity as an unfit factor in some labor forces. Also, the hired workers usually have good access to medical services which may keep these workers away from diseases.[13] Thus, there are some factors which may not be noticed and controlled during the comparison between the occupational cohorts and the general population in the morbidity and mortality studies. This situation, which is related to 'good health status' (confounding factor), may create an association between exposure ('employment in the industry') and other factors that can affect the outcome (morbidity and mortality rates). However, there is another school that considers HWE as a mix of selection and confounding bias at the same time, where it is difficult to differentiate between them in the presence of HWE.

The most important issue here is the understanding of the nature and sources of the HWE, as well as the factors that may cause it. This paper is a comprehensive review to understand in depth the HWE, through exploring its effects and magnitude, sources, factors, and the strategies to reduce it, among available occupational epidemiologic studies.

REVIEW OF LITERATURE

The effects of HWE on research and clinical perspectives

The HWE bias, an unwelcomed influence, has serious impacts on both research and clinical perspectives. Most occupational epidemiologic studies may encounter the risk of this bias, especially if they are studying workers' health. These studies may have a reduction about 20-30% in the association between the exposure and the outcome.[3,12,14] Moreover, the HWE causes a reduction in the overall death rate between 70% and 80% among workers using the general population as a reference group.[12] Unfortunately, HWE may distort the morbidity and mortality rates by masking or underestimating the real values of harmful exposures in the occupational settings or workplaces partially or completely.[7,15]

Sources/components of HWE

According to the literature, there are many components or sources of HWE that can be classified under the following four main components:

Healthy hire effect

The healthy hire effect is 'the initial selection process whereby healthy individuals are more likely to seek and gain employment than are less healthy individuals. [16] It is the second most important source for the occurrence of HWE. Basically, the employers may aim to avoid recruiting workers who are high risk. In fact, the hiring process requires passing some medical examinations to get the job. However, this may differ from employer to employer based on the labor situation and labor shortages.[2,3,12,15] In a previous study done by Choi (2000), he found the relationship between firefighters and heart diseases is influenced by HWE due to the 'strong selection for non-diabetic individuals to be fire fighters. It

is known that diabetes is a risk factor for heart disease.[17] Unfortunately, insufficient consideration for the non-diabetes requirement caused the previous studies among firefighters to conclude that there is no HWE among firefighters with respect to the death rate due to heart diseases.[18]

Time-since-hire effect

The time since hire effect is the period that has been followed since hiring for the targeted population. With respect to the HWE, the failure to completely follow the workers who leave work may obstruct the determination of the worker's vital status or health status. The bias may also come from the presence of a higher number of recent hires, who have lower cumulative exposure, compared to earlier hires, who have higher cumulative exposure. However, the changes in the worker's health status may be related to different factors other than the exposure.[2,5,15] In fact, the incomplete follow-up is a source of HWE bias that may be due to two factors: i) the workers with good health would continue in the employment while, ii) the workers with bad health would tend to leave the employment due to sickness.

Therefore, the morbidity and mortality rates from the observed occupational cohorts for a period (follow-up) would be lower than the general population due to these two factors.[1,12] It was found that the SMRs were highest during the first 5 years after work termination, while the rates for those who could survive after 5 years were not different in comparison to the general population rates among rubber workers, who stopped working before age 65.[19] Thus, the termination may indicate that the healthy worker survivor effect (HWSE) bias was responsible for these rates. On the other hand, previous evidence reported that early termination was not 'a predictor of early mortality.[20]

Healthy worker survivor effect (HWSE)

The healthy worker survivor effect is 'the continuing selection process whereby healthy workers are more likely to be retained in the workforce over time than are less healthy individuals.[16] Some workers may not have good health to seek jobs; therefore, they do not ask for jobs (self-selection).[21] In fact, this source (HWSE) and the healthy hire effect (employer selection for healthy workers) are the most important sources for the appearance of HWE.[2,3,12,15]

In the occupational morbidity (non-fatal outcomes) studies such as workers with asthma or musculoskeletal disorders, it is a common phenomenon to find sick workers leaving the employment or transferring to less-exposed occupations. This situation makes these studies more prone to HWE bias.[15] In fact, there are two types of HWSE: i) transferring to another job with less exposure, or ii) leaving the work due to the poor health status. The understanding of these two types is very important because this helps in detecting and controlling/removing the bias.[10] The longitudinal studies are more prone to have HWSE among sick workers who leave their work compared to the cross-sectional studies that include all workers, even the sick workers, who may subsequently leave during the period of follow-up.[21] However, the cross-sectional studies may only include the active workers (healthier workers), as the workers with poorer health may have already left the workplace before the beginning of the study; therefore, the effects of the exposure may be underestimated. Finally, if the HWSE was not considered, there might be 'an underestimation of the risk of disease for exposed workers.[22]

Beneficial effect of work

The employed workers usually have good access to health services that provide frequent disease screening as well as physical exertion/exercises that help in the reduction of some diseases like myocardial infarction or blood pressure.[12] Consequently, the workers may get these benefits as well as a 'higher standard of living' from work.[3,23] However, this component may not be completely agreed upon by all investigators compared to the previous three sources/components.[3,12]

Factors affecting the HWE

HWE is a dynamic bias and it varies based on the comparison population and some factors. These factors may differ from one study to another.

Time related factors

Time related factors that have an impact on the HWE: age at risk and at the entry time of employment, duration of employment, and the period of follow-up.[1,24,25] The good health advantage at the entry time of employment gradually decreases as time increases. These periods fluctuated among studies between 10-20 years, and 5-25 years.[12] On the other hand, other investigators such as Sterling and Weinkam did not consider time as an effect modifier and they insisted that the HWE is present during the lifetime of the workers.[26]

Age

Age is one of the factors that affect the HWE.[1] The HWE increases as age increases.[26] Fox and Collier found that the younger workers had lower standardized mortality ratio in comparison to older workers.[27] This is in disagreement with the common belief that the actively older workers are healthier than their counterparts of the same age in the general population.[2,28] There were some mortality studies which found that as age increased, the HWE also increased and became stronger, especially among workers who were hired at or after age 40 and 45 years old compared to workers who were hired before age 40 and 45 years old.[27,28]

Duration of employment

The longer period of employment would increase the likelihood of HWE, as the unfit/unhealthy workers would either leave the work or at least move to work with less-exposure.[3] The duration of employment is associated with the exposure level because the recent workers would have lower exposure level and shorter time of follow up; consequently, they would have lower mortality or morbidity rates. Actually, this supports the fact that HWE would be higher or stronger in the first period of employment.[1]

However, as time increases the SMR may also increase for some diseases as a result of a consequence of accumulated hazardous exposures rather than the disappearance of the advantages of the health selection process at employment. Long term workers are more likely to tolerate 'higher levels of cumulative exposure than short term workers' because they may have a protective effect.[29] The healthy workers usually tend to maintain their employment for longer periods of time compared to the short-term workers who may have some unhealthy behaviors, which may affect their continuity in the employment.[30] Also, it was found that the short-term workers had higher mortality rates compared to long term workers.[8,31] Therefore, it is necessary to adjust for the duration of employment to avoid the bias of the HWE in the rates.

Period of follow-up

The HWE is more likely to occur at the initial time of follow up or hiring while it reduces over time of follow-up.[13] A previous study found that the HWE may last up to 15 years while another study reported that the HWE fluctuated between 5 to 25 years.[13]

Causes of morbidity/mortality

The probability of the HWE may increase or decrease based on the type of disease. The HWE may have a higher probability among nonmalignant diseases that occur at a younger age such as endocrine, digestive, urinary system diseases, and nonmalignant diseases of the respiratory system. These diseases are related to the health condition of workers that may prevent them from working.[16] Second, the diseases that are considered 'long term chronic diseases' such as cardiovascular diseases, which may interfere with employment, may also have a higher probability of the HWE. Also, the HWE may have lower probability among some diseases like cancers that are not easy to be identified at the time of hiring.

Socioeconomic status and type of occupational cohort

Socioeconomic and occupational classes may affect the HWE. The higher the socioeconomic status the higher would be the probability of HWE occurrence. According to previous mortality rates showed that workers in the lowest grades were 10 times higher to die than workers in the highest employment grades.[32] The SMRs were also found to be lower among workers in the highest occupational class in comparison to workers in two lower occupational classes for all cancers.[33] In other words, the type of workforce would influence the HWE because, for example, the occupations with high physical demands would have a higher probability of having HWE compared to other occupations that do not have physical demands. In brief, the jobs with higher physical demands or higher exposure level would have a higher probability of HWE.[2]

Social conditions at the time of employment

The HWE is prone to change based on the type of social conditions. In periods of time requiring high recruitment such as wars, employers may not exclude workers, even if they have a high risk of disease. But employers may be more restricted in their recruitments during periods of stable social conditions and exclude workers who are considered unhealthy or at least have high risk factors of diseases.[10]

Race

Race also may affect the occurrence of the HWE. It was found that the HWE is more likely to occur among non-whites compared to whites' workers in the US population.[8,18] The non-white workers were compared with the national average for non-white population that had low socioeconomic class, whereas the white workers were compared with the national average of white population that had average socioeconomic class. Therefore, this may be attributed to 'the social class disparity between employed and unemployed subgroups of the US population.[8]

Gender

Gender is one of the factors that would affect the HWE.[1] In a previous study, women had stronger HWE in comparison to men.[21,34] On the other hand, according to Hernberg, it was reported that men are more likely to have HWE compared to women, who usually are more probable to not being rejected from employment due to their poor health status, as their male counterparts.[1] In a previous study, the women had stronger HWSE, whereas the men had stronger healthy hire effect.[35] In brief, gender is considered a very important factor of HWE based on the different circumstances and biological differences between male and female workers.

OTHER FACTORS

There have been other factors mentioned in some previous studies such as:

Improper comparison between local and national cohorts

This may occur when there are differences in the quality of health care in a region (having better health care) compared to the large population in the country, where the mortality and morbidity rates would be lower for the regional population.

Errors existing in the used data base

These errors might lead to omit the dead workers for some reasons during any development (e.g., reconstruction) or updating for a company data base. This would reduce the studied rates (e.g., mortality) in the cohort sample and distort the whole data base.

Using the general population as a comparison group

The general population is not considered a good comparison group due to the different characteristics between the actively employed workers and the general population. The general population usually has many individuals who are unable to get jobs because they are unfit or unwell. The HWE may be considered simply as a comparison issue in nature, which is a result of an inappropriate reference group. [3] Therefore, there is a very important question which can be asked here: Why do we need external comparisons? Possibly the answer may be:

The comparison with an external population would help in providing more information than the comparison with a smaller sample within the same occupational cohort. However, that requires similarity with respect to the exposure variables.[16]

The using of external national rates, which have large numbers, would help the cohort studies with small numbers to have more stable estimates compared to using an internal cohort as a reference group.[36]

The difficulties in finding a large working cohort (reference group) that have the same characteristics as the study sample (occupational cohort) except exposure.[37]

The availability of national mortality/morbidity rates.[36]

Choosing the inappropriate reference population

This can occur when the reference population has different exposure than the targeted population, but both have the same outcome (e.g., cancer).

DISCUSSION

Strategies for minimizing HWE biases

There are some strategies that help in reducing the HWE, but every strategy has its advantages and disadvantages. The most feasible strategies may be the usage of external or internal comparison groups.[2] Moreover, there is another strategy that is considered the most straightforward strategy which is avoiding the usage of "general population as a reference group.[3] Unfortunately, the best solution for the reference group is almost impossible or difficult. However, it is important to note that not all strategies are applicable for all occupational epidemiological studies.[26]

Minimizing healthy hire effect

The usage of internal work comparison groups may minimize the healthy hire effect. It would provide similar employees, who may have a similar hiring process and experience similar confounding effects. This strategy may provide more accurate and thorough information regarding occupational diseases and disorders.[2,12,25,26] By using the internal work comparison groups, the differences regarding the confounding factors would not be as big as by using the general population or external work comparison groups.

Minimizing time-since-hire effect

The usage of only internal work comparison groups may minimize the healthy hire effect, but not the time since hire effect bias. Therefore, there is another strategy which involves stratifying time since hire among workers with shorter or longer time since hire considering the high and low cumulative exposure. In addition, the longer the follow up time for the occupational cohort, the lower the influence of the HWE. Therefore, the investigators should maximize their follow up period as much as they can to reduce the HWE.

Minimizing healthy workers survivor effect

The selection bias of HWE can be reduced by including all workers: active workers, pensioners and even workers who left the employment before retirement age.[2] This can be done by tracing and including all occupational cohorts, regardless if the workers still actively work or leave the work before the retirement age, as some workers usually do, due to health issues.[12] A previous study stratified the workers into either active or non-active workers.[26,38] It was found that the mortality rates were higher among non-active workers compared to active workers before the retirement age of 65 years, while these higher rates were not found after the age of retirement among the non-active workers. This can be seen as evidence that the active workers were healthier than non-active workers, who leave the work before retirement age.[39] Therefore, stratifying based on employment status (active versus inactive) may help in reducing HWSE. However, this stratifying has some disadvantages. For example, the inactive group would be a heterogeneous sample because this group usually has different reasons for their inactive employment status (e.g., disability, retirement, self-employed etc.). Also, this strategy does not help in cross

sectional studies that usually include only active workers.[15]

There have been other strategies such as

Excluding the first 5 or 10 years after hiring

There is a strategy which excludes the first 5- or 10-years period after hiring. Using the 10 years of latency may be useful in decreasing the HWE.[26] But this would affect the statistical power due to the small sample size after the restriction for exclusion 10 or 15 years after hiring time. Also, Applebaum et al recommended that minimizing the HWSE can be done by 'restricting the date of hire to be close to the start of follow up' and identifying the workers who just start the employment and include them in the study.[40]

Mathematical procedures to adjust for the HWE

There have been some mathematical procedures to adjust for the HWE suggested by some authors, Sterling and Weinkam [40] and Choi, [41] but unfortunately these methods still need further investigations to be proved and validated. A recent study also showed that G-estimation may be a better method to adjust for the HWSE compared to other standard methods. [42]

The usage of external work comparison groups

The usage of correct external work comparison groups (reference groups) should include workers who work in specific jobs have comparable selection process and have the similar extraneous effects on the studied outcome. [2, 12]

The usage of a proper geographical comparison group

The reference group must be chosen based on the geographical area by avoiding the comparison with urban reference groups, if the occupational cohort is rural and vice versa.[12]

The HWE appears to be a comparison issue in nature due to the inappropriate comparison groups. The HWE is more appropriate to be considered as a selection or confounding bias or both. All researchers in an occupational epidemiology field should show how they did avoid the underestimated values due to the bias of HWE. The HWE comes from four main resources: healthy hire effect, time since hire effect, healthy worker survivor effect, and beneficial effect of work. There are several factors which can increase or decrease the probability of HWE. The usage of strategies that reduce the HWE is helpful, but each strategy has its strengths and weaknesses.

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