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A Primer to Experimental and Nonexperimental Quantitative Research: The Example Case of Tobacco-Related Mouth Cancer

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ABSTRACT

Objectives: To present a comprehensive overview of key constructs of experimental and nonexperimental quantitative research, drawing on one example case from cancer care.
Data Sources: Published scientific articles, research textbooks, and expert advice were used in this article.
Conclusion: Quantitative research turns information collected about people or about processes into numerical data. Depending on the underlying purpose, the goal is to address questions that have to do with intervention, prognosis, causation, association, description, or assessment. In experimental research, an intervention is manipulated. True experimental research (randomized controlled trial) controls confounding variables via use of both randomization and a control group; quasi-experimental research misses one or both of these elements. In either case, the aim is to generate evidence to confidently say that an intervention is the true cause of an observed outcome. Nonexperimental research is multifaceted. Cohorts and case-control studies can be used to test cause-and-effect relationships where experimental research is unethical or impractical. Correlational research aims to explore possible associations (exploratory) or help anticipate outcomes (predictive) and, quite often, is the precursor of experimental research. Descriptive research (simple, comparative, survey, retrospective chart review) can be used to describe and assess situations, conditions, or behaviors.
Implications for Nursing Practice: Understanding the different aims and goals of the different types of quantitative research can help increase capacity and confidence in understanding, appraising, and applying quantitative evidence among health care students, professionals, and novice researchers in the quest for the provision of quality cancer care.

Introduction

If you have ever been curious about terms like *clinical trial*, *correlation study*, or *survey*, then this article is for you. It will hopefully help you gain a better understanding of what these and many more related terms mean as they all fall under the wider umbrella term of *quantitative research*. Here, we will focus on the fundamentals of quantitative research and explore major areas of inquiry with the aid of a real-world example case, that of tobacco-related mouth cancer.[1]

Features of Quantitative Research

Quantitative research is based on a distinct philosophy or perspective of the world around us: positivism. Positivism claims that there is a single, unique truth or reality that is constant across time and setting.[2] Moreover, this single truth can be measured numerically and objectively, it can be confirmed and then generalized to others. Finally, this single reality can be measured independently of the researcher; it exists irrespective of the researcher—or anyone else among us really. Positivism is shrouded in this kind of romantic naivety that claims that however you measure reality, you always get it right simply because reality cannot be disputed. If you now think that it is entirely possible that some measures can be biased or inaccurate, then you are correct. If you also think that health care is far too complex for a unique truth to be uncovered for every construct, process, or situation, you are also correct. These are notions of the philosophies of post-positivism and critical realism.[3-5] These philosophies still accept the concept of a single, unique reality and focus on observations of the mechanisms of this truth or reality.[6] They nevertheless accept that measures can be fallible simply because measures and measurements are the product of humans, who are inherently imperfect and prone to error.

The hallmark of quantitative research is that it deals with numbers; it turns information collected about people or processes into

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numerical data. Quantitative research often creates large amounts of such numerical data that initially are of unclear meaning. Quantitative researchers use statistics and sophisticated software packages to analyze their data. Analysis helps describe the data, identify patterns, test relationships, or make predictions.

Another feature of quantitative research is that it aims to place control over what is being researched; its goal is to minimize systematic error, also known as bias.[2] If there is one unique truth out there, then quantitative researchers want to be able to measure it accurately and consistently. Potentially, all types of quantitative research can be affected by bias.[7] However, if quantitative methods and measurements are accurate and consistent enough, then researchers may be able to claim that observations, findings, and conclusions derived from studying a “sample” of people might apply to the average person and, subsequently, can be generalized to the target population where their sample came from. This is the feature of generalizing evidence from a study group (sample) to similar larger groups that come from the same target population. For instance, if researchers have quantified survival rates among patients with head and neck cancer from clinics in their local hospital (ie, quantitative results from the sample), then the question that follows is: Are survival rates of patients with head and neck cancer similar in the same region or even across the country (ie, can it be generalized to the wider target population)?

Areas of Inquiry in Quantitative Research

There are two broad areas of inquiry in quantitative research (Fig 1). There is research that aims to describe or explore diseases, conditions, or variables; and there is research that tries to find a causal relationship among variables, conditions, and real-life situations.[2] These two fields of research do not exist independently; they talk to each other. When researchers start to identify a solution to a health problem, they first describe their observations. They then explore to better understand what the problem is and make hypotheses about what potentially causes it. The inquiry does not stop here of course. Remember that quantitative research aims to uncover the truth, so quantitative researchers strive to verify their hypotheses and generate strong evidence about what is true for most people, what causes what, or whether treatments work or if they are safe.

Imagine that the focus of quantitative research is cancers of the oral cavity and the effects of smoking. Over the past decades there has been extensive research to establish a link between smoking and development of mouth cancer.[1] Where do you think this research has its origins? Perhaps it was curious clinicians who first went through the medical records of their patients with a mouth cancer diagnosis. Someone must have noticed that there were a lot of smokers or former smokers among the total of patients with mouth cancer. This initial type of research involved a preliminary assessment and the formation of a hypothesis: Is smoking somehow linked to mouth cancer? In parallel, other researchers might have surveyed the public to understand how many people at the time were smokers. They might have wanted to describe the percentage of smokers in the total population of a country. Again, someone must have noticed that quite a few smokers also reported to have health problems, and one of them was mouth cancer.

These first observations may have made researchers even more curious. Is there an association between heavy smoking and damage to the oral cavity tissue? Can this “link” be quantified and explored? They probably analyzed data from many people to find that a correlation existed between these two variables. The longer people smoked, the larger the damage to their mouth tissue.[8] As such, the next couple of questions must have come to them naturally. Does smoking *cause* mouth cancer? Does the type of tobacco smoking matter? Is mouth cancer an *outcome* of prolonged heavy smoking? The scientific community were now interested to find *concrete evidence* that smoking causes cancer. Another round of research was done to try and create evidence to support this hypothesis.

After years of research, smoking has now been established as a causal factor of cancer. Today, there is also a lot of effort placed on developing and testing ways to prevent cancer due to smoking. Equally, for those smokers who do develop cancer, new treatments are tested to help those former smokers who are diagnosed with mouth cancer. For instance, they try to establish whether cisplatin combined with radiotherapy to the mouth increases survival rates of patients with mouth cancer.[9] In other words: How sure are we that if patients live longer, it will be because of this treatment combination? It is apparent then how many purposes quantitative research can serve. Some purposes focus on describing or exploring a problem, whereas others are concerned with establishing a cause-and-effect

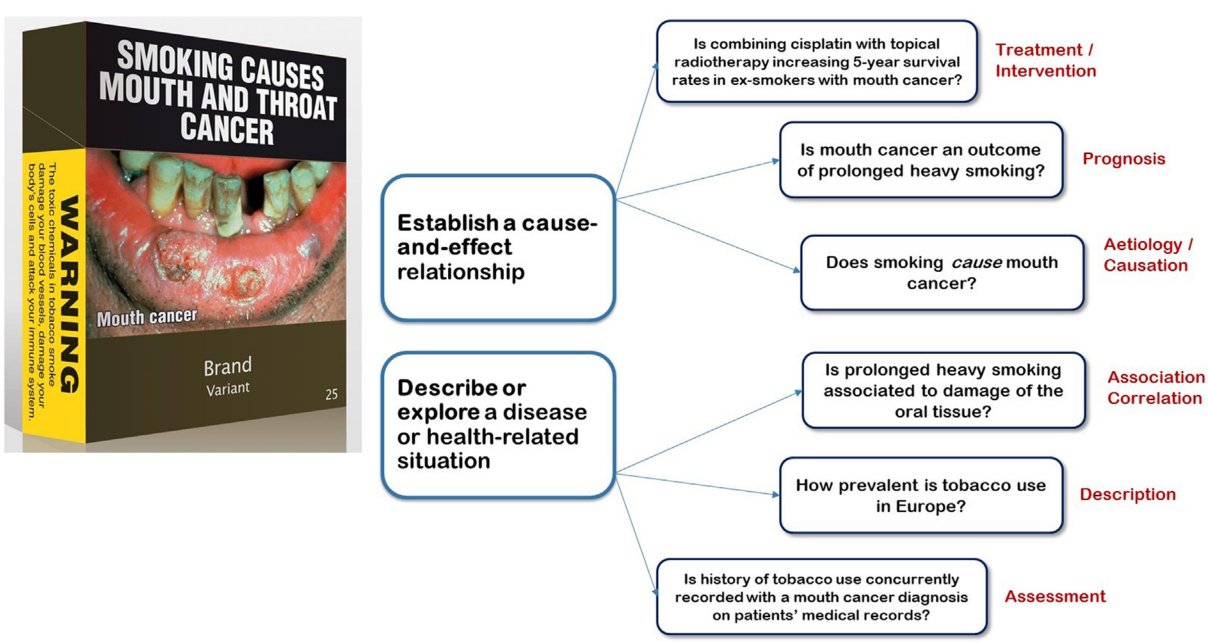

FIG 1. Two broad areas of inquiry in quantitative research, with associated purposes and questions in the example fields of mouth cancer research.

relationship. For each of these purposes (Fig 1), different types of quantitative research can be used to create credible evidence. Let us explore each one of these purposes and associated types of quantitative research in greater detail.

Purpose: Treatment/Intervention

Suppose that the idea is to find credible evidence that cisplatin and topical radiotherapy do help patients with mouth cancer to live longer.[9] Treatment is the cause (or independent variable), and patients' survival is the effect (or dependent variable or outcome). It is important that researchers show that the treatment is indeed the cause for longer survival and not any other variable, including self-healing. To be able to show a credible cause-and-effect relationship, researchers must try and limit as much as possible interference cause by other factors (ie, they need to control [all] relevant confounding variables, such as size of tumor, the patient's age, duration of smoking, and so on). Control is important to help say with confidence that the independent variable truly causes change to the dependent variable.

There are several ways to impose control (Fig 2). Manipulation of the independent variable is the first one. Manipulation is possible where the researcher has full control over the independent variable; this is true in the case of a treatment or intervention.[2] For instance, researchers can purposely change the dosage of a medication to see what the effect different doses might have on the patient. They might combine cisplatin with radiotherapy as a new revolutionary treatment. Or they might rely on what is current practice (ie, offer only chemotherapy, only radiotherapy, or only surgery). They might use a watchful waiting approach to monitor patients closely to see how the tumor develops. Or they might even give no active medication to patients; what you might have heard described as placebo.

Manipulation alone is not enough. Researchers want to know what happens when the same patient takes and, at the same time, does not take the new treatment—in our case the combined chemoradiation. This way, if the patient shows improvement, researchers can be able to tell that it really is down to the new treatment. Getting and, at the same time, not getting the new treatment is of course impossible. However, this counterfactual must somehow be met. This is why researchers split participants into distinct groups. One group they call intervention or experimental group; participants in this group get the treatment of interest. The other group (or groups) is known as the control group; they either receive no drug or a sham drug (the placebo) or another dose or another drug that is already used in clinical practice. If the experimental and control groups show considerable differences on an outcome of interest (eg, survival), then the researchers might be able to say that the observed difference is because of the new treatment.

There is a third aspect that must be controlled. The experimental and control groups must be roughly similar in terms of demographic and clinical characteristics of interest before the study begins. If they are not similar, then any differences can act as confounding and lead to error or bias. Suppose that researchers simply choose who will take the new treatment and who will not. It may happen that most participants in the intervention group have early-stage mouth cancer, and the control group happens to involve most people with advanced stage mouth cancer; thus, the two groups are dissimilar regarding cancer stage. It is then entirely possible the intervention group might show artificially greater benefit while on treatment; in reality, however, this cannot be deemed as a true treatment benefit. This is more the impact of confounding given that early-stage cancers are de facto more easily treatable, and the typical patient with early-stage cancer is bound to live longer compared to the typical patient with advanced cancer. In another example, suppose that the researcher tries to be fair and assign the first few patients randomly to experimental or control group, but now the next patient is a young woman who can really benefit from the new treatment. The researcher decides to deliberately assign this patient to the experimental group, but if they did so for every other young patient, the experimental group would be disproportionately younger compared with the control. If the researcher found that the new treatment did benefit the experimental group, they would not know whether it was because of the new treatment itself or because the drug was better metabolized in younger patients; now, the patients' age becomes a confounding variable, and the researcher cannot establish a cause-and-effect relationship.

Quantitative research is about being objective. To ensure that experimental and control groups are similar and confounding variables are controlled, researchers use randomization. Randomization ensures that every patient has an equal chance (50:50) to be on the experimental or control group. Today, randomization is facilitated by computer programs that assign people to experimental or control groups, taking into account details such as age or clinical features, to make sure that the groups are indeed as similar as possible before the research begins.

Manipulating the intervention or treatment using a control group and using randomization are core features of what is called *true experimental research* or a randomized controlled trial (RCT) (Fig 3).[2]

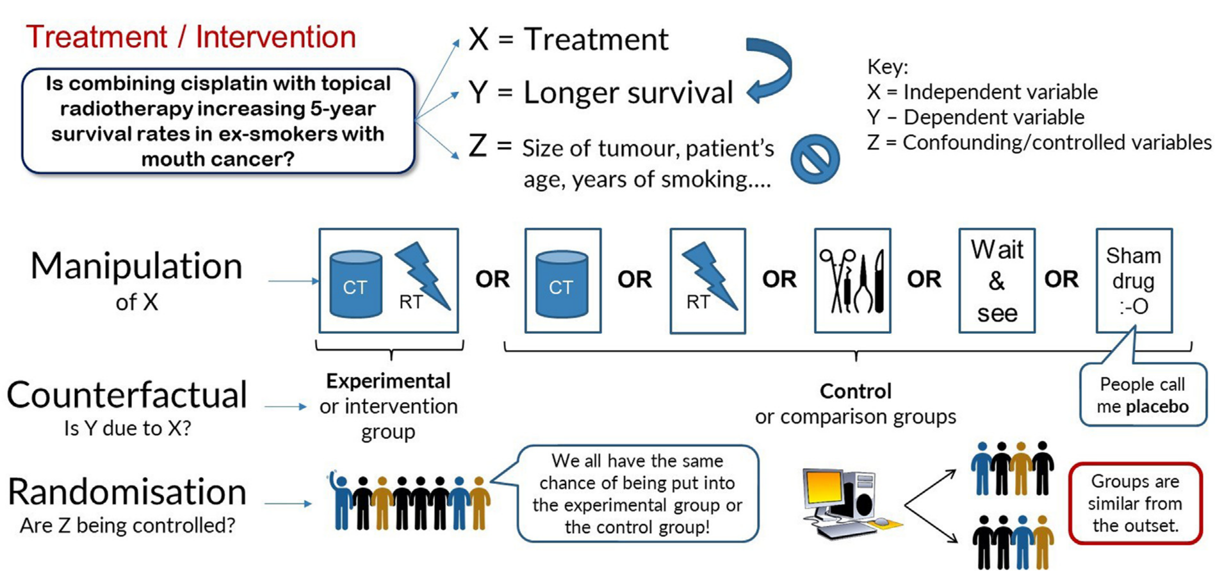

FIG 2. Main ways to impose control in experimental research.

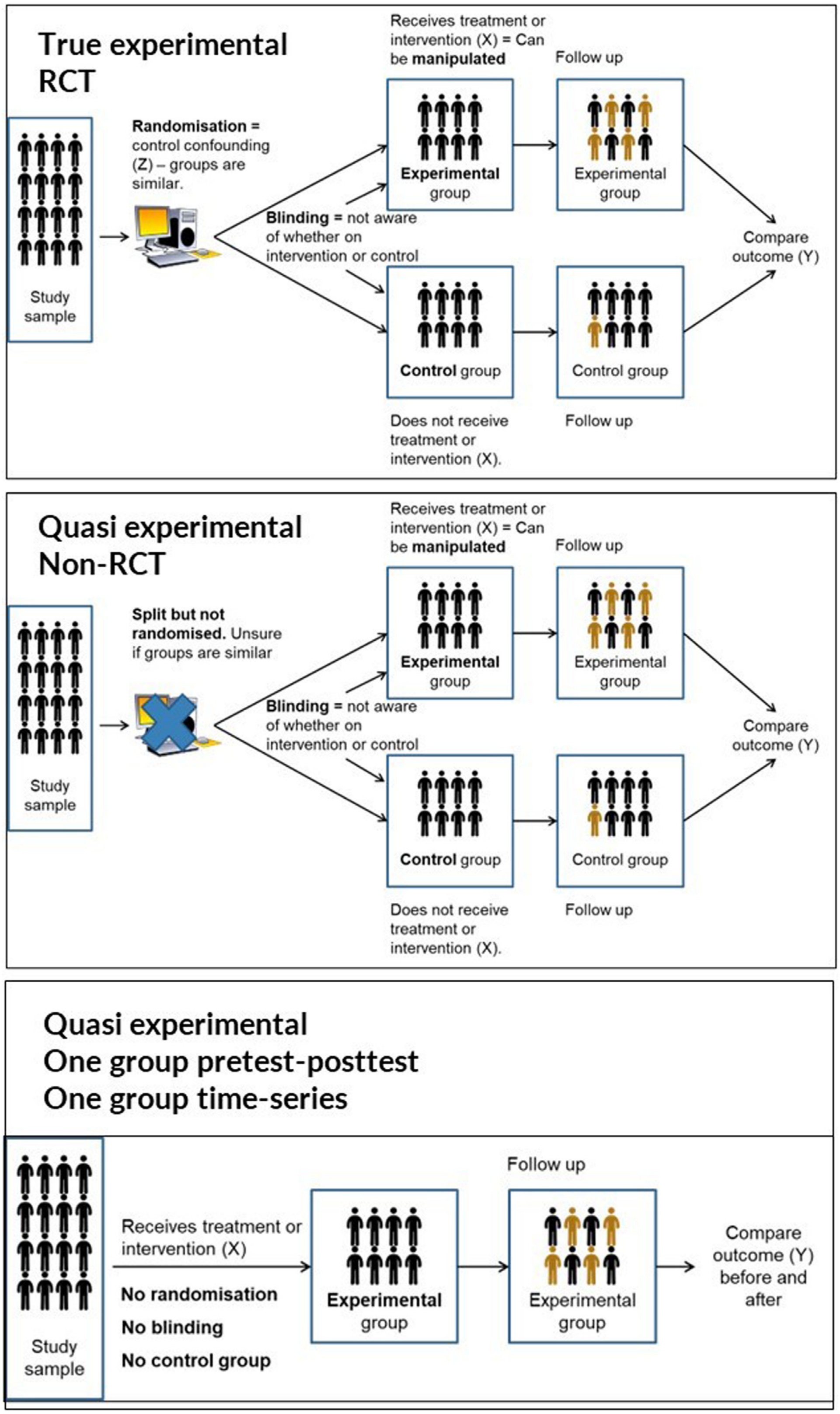

FIG 3. True and quasi-experimental research.

Blinding (or masking) may also be used in RCTs and non-RCTs to minimize expectation bias.[2] Participants are not simply randomly assigned to experimental or control group, but also they are prevented from knowing which group they've been assigned to. This is so that the outcome of the treatment or intervention is not influenced by their expectations; those in the experimental group might do better even by knowing that they get a new promising treatment. Those in the control group might do worse if they are disappointed because of not getting the experimental treatment or intervention. Psychology is involved here. Blinding (or masking) is particularly important in drug trials. For instance, participants receive the same round, yellow pill although what is inside the pill differs between the groups; it can either be the new drug or another drug or placebo.[10]

One might wonder: why are we talking about "true" experimental research? Does this mean that there is also "false" experimental research? Not false per se, but quasi-experimental or "almost experimental" research. In quasi-experimental research, one or two of the three core elements we discussed is not present (ie, either randomization only is missing or both control groups and randomization are missing [Fig 3]). Manipulation will still be present because it is the defining characteristic of any experimental research, true or quasi.

As it happens, sometimes randomization is not practical; therefore, researchers may well decide to test a new treatment or intervention using experimental and control groups without randomization. This type of experimental research without randomization is simply known as a nonrandomized controlled trial, which is easy to remember. A control group is still present, but randomization is not. In other cases, researchers might have to rely on one group only (the experimental) to apply their intervention. They may evaluate the participants before the study and then evaluate them again after the end of the treatment to see what has changed. If there is only one test done before and one test after, this is called a *one-group pretest-posttest study*. If there are several tests done before and after an intervention is given, this is called a *time-series study*.[2]

In either case, patients might show some benefit. This might be because of the treatment, but it is possible that patients get better without the intervention. Researchers simply cannot know with confidence. We discussed previously the strengths that randomization brings with it. As such, in quasi-experimental research, the risk is greater that considerable differences between experimental and control groups might act as confounding that interferes with the cause-and-effect relationship between an intervention and its hypothesized effects. Therefore, it is more difficult to confidently say that the intervention truly works. If a control group is also missing, then this becomes even more difficult. Of course, this does not mean quasi-experimental research is useless; however, it is less rigorous in terms of control. To be fair, quasi-experimental research likely reflects real-world challenges in organizing a randomized controlled trial. A randomized controlled trial is not always practically possible, so alternative ways must be found to generate preliminary evidence. Probably, the only exception is when testing new medications. All new medications must be tested for efficacy and safety against standard care.[11] Phase 3 clinical trials are large-scale true experimental studies to create strong evidence that the medication works and is safe before it is approved for clinical use.

Purpose: Prognosis/Etiology

Besides testing a new treatment or intervention, there are many other questions that seek to establish a cause-and-effect relationship. Going back to our original example, there is evidence that smoking *causes* mouth cancer and perhaps other oral cancers. How come researchers talk about a *causal* link between smoking and cancer? Were they able to perform an experiment? Thinking of experiments, the first question we should ask ourselves is this: Can the independent variable be manipulated? Here, the independent variable is smoking. If manipulation was possible here, then it would suggest that researchers *actively* expose people to smaller or larger amounts of nicotine to see if they develop cancer. This is far from testing a new medication to establish benefit. This kind of experimentation has the potential to cause harm and is purely unethical. The answer here is no; this independent variable cannot be manipulated. To be able to find a causal link between smoking and cancer, or more generally, find the cause to any disease, we cannot rely on experimental research. This is why nonexperimental research exists (Fig 4).

Nonexperimental research, as the name implies, tries to establish a cause-and-effect relationship without experimentation. Nonexperimental research can be used where manipulation of the independent variable is not possible or ethical. This is the case in studies that deal with questions of prognosis or etiology.[7] Researchers must still be able to control any confounding variables that interfere in the relationship between, for example, smoking and mouth cancer. They can still use multiple groups for comparison; however, randomization is not possible, and we will see why.

Let us start with questions of prognosis. Studies that answer such questions are called *cohort studies*.[2] Cohort studies look forward to the present and to the future. A cohort simply implies a large group of people. This group is split up in two cohorts, one is the cohort of people exposed to the independent variable, smoking in our case. The other cohort is the nonexposed group, the nonsmokers.

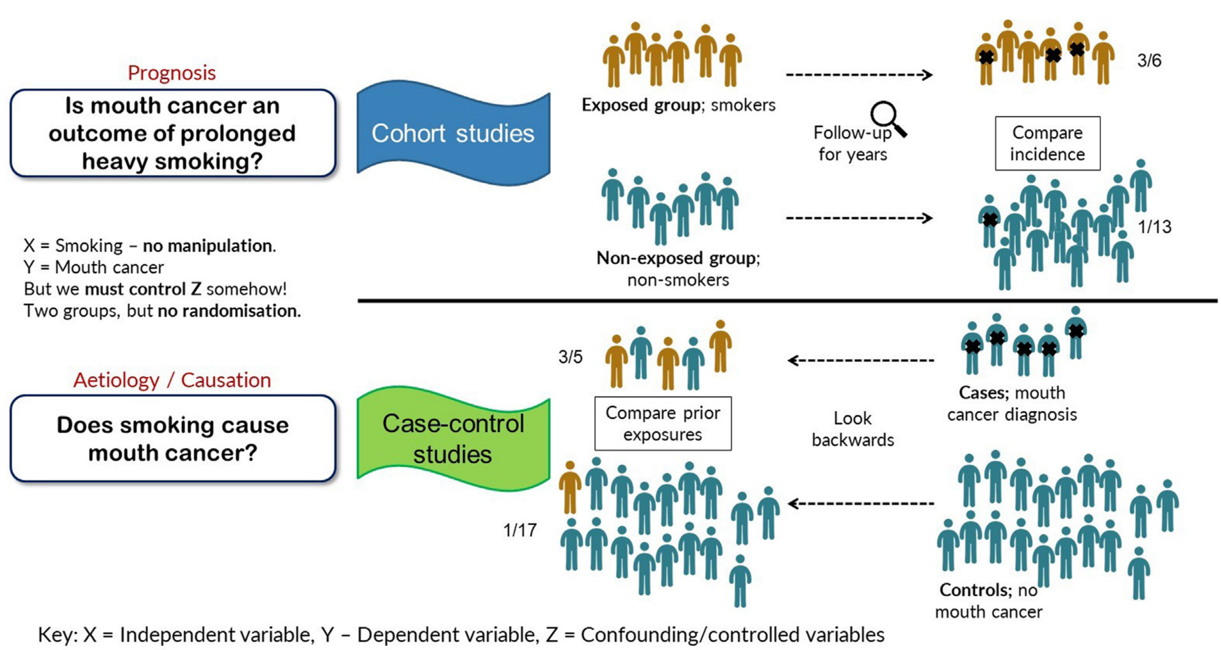

FIG 4. Cohort and case-control studies as examples of nonexperimental research to help establish cause-and-effect relationships.

Obviously, whoever goes in either of these groups is because they have a smoking habit and not because they were assigned or randomized to this group. In cohort studies, researchers follow up very large cohorts of people (even thousands) over long periods of time, decades even. For instance, Jayalekshm et al[12] followed more than 66,000 men for 15 years. The purpose is to see how many people in either group will develop the outcome of interest; in our example, mouth cancer. Researchers then compare the incidence of mouth cancer in the two cohorts. In the fictitious example in Fig 4, 3 in 6 smokers (50%) developed mouth cancer compared to 1 in 13 among the nonsmokers (8%). This difference gives an indication that smoking might be one of the causes of mouth cancer. The probability of getting cancer is much higher in smokers compared to nonsmokers. Having a comparison group, the researchers can statistically control for any other confounding variables, such as alcohol use. If the cohorts have the same number of alcohol users, then this confounding variable has been controlled. Of course, this cannot be predicted, but the fact that cohort studies rely on so large numbers of participants increases the odds that the two cohorts will be similar.

Another way to establish a relationship between smoking and mouth cancer is to conduct a case-control study.[2] What is similar to the cohort study is that again there are two groups for comparison. However, case-control studies work in a different way. While in cohort studies researchers wait for years to see whether people are going to develop the disease, case-control studies rely on data from people who have already developed the disease. These people are the cases. For comparison purposes, researchers also select another group of people without the disease. These people are the controls, hence, the name case-control study. See an example from Tenore et al,[13] who looked at a test and control group, each involving 239 patients. Case-control studies look backward (ie, to the past). Researchers examine the health records of the two groups to identify differences in prior exposures. If they look to see who was a smoker (Fig 4), they might find that 3 in 5 people (60%) who got mouth cancer were previous heavy smokers compared to 1 in 17 in the control group (6%). Again, if the groups are fairly similar, confounding variables can be controlled. Case-control studies are much smaller than cohort studies, and one way to control for confounding variables is to match each person on the case group with a similar person from the control group in terms of age, gender, alcohol use, and so on. This way, the two groups can hopefully only differ in terms of smoking. And in doing so, researchers can be more confident in saying that prior exposure to smoking likely causes mouth cancer.

Cohort studies generally provide stronger evidence because of their prospective nature that allows the outcome to be naturally developed instead of relying on retrospective data like in case-control studies.[2] Both types of research can control a great number of confounding variables; however, several of them remain uncontrolled due to absence of randomization, and for that reason, they are generally considered less robust than true experimental research.

Purpose: Association/Correlation

There is a large field of nonexperimental quantitative research that seeks to explore possible links between variables or situations. Suppose that researchers were looking to explore the possibility for a link (also known as *correlation*) between prolonged heavy smoking and damage to the tissue of the oral cavity; this is an example of correlational research.[7] Here, researchers want to see if years of smoking and degree of tissue damage are associated somehow. Correlational research can be exploratory to establish whether a novel hypothesized correlation seems to exist.[7] Two variables can be positively correlated; when one variable increases, the other increases too, (eg, when years of smoking go up, damage to the oral tissue may be greater). Two variables can also be negatively correlated; when one variable increases, the other decreases (eg, better dental hygiene may be linked to smaller damage to the oral tissue). And of course, two variables may not be correlated at all; there is no evidence for a link between them (Fig 5). For instance, Sujatha et al[14] found a positive correlation between readiness to quit and patients' perceptions on the positive impact of quitting tobacco on their health.

Correlational research can also be predictive. This usually follows upon exploratory correlational research that has already explored and evidenced a correlation between two variables. In predictive correlational research the focus is on identifying which ones from a series of variables might predict change to the variable of interest. For instance, de Granda-Orive et al[15] found that, among several other variables, initial high levels of motivation to quit smoking most strongly correlated with sustained long-term abstinence. Establishing associations is good because it can help researchers and clinicians to *anticipate* outcomes. Indeed, a function of establishing a numerical relationship between is variables to pave the way toward *prediction*.[7] However, simply establishing a correlation is not enough to *prove*

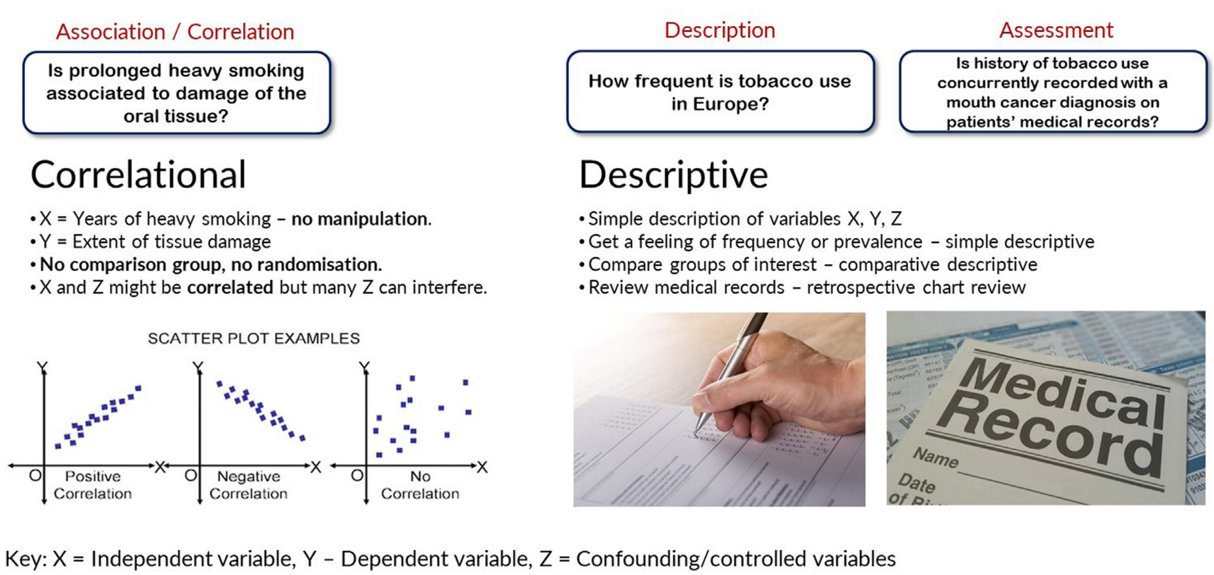

FIG 5. Examples of nonexperimental research that deals with association, description, or assessment.

one thing *causes* another, and this is because several confounding variables might interfere or provide alternative explanations for this correlation. This is why one very popular quote (and very true one) is: Correlation is not causation.[16]

Purpose: Assessment/Description

Moving beyond links, associations, and relationships, there is research that simply assesses situations and describes variables to help researchers better understand the frequency or incidence of different health problems or issues There are many descriptive designs, including simple (one group being assessed), comparative (two or more groups being assessed and compared), cross-sectional (one single assessment), and longitudinal (two or more consecutive assessments).[7] These designs can be used alone or in combinations; see, for instance, a comparative descriptive study by Gray et al[17] that involved patients with oral cancer split up into two groups, 88 ever-smokers and 115 never-smokers.

Surveys are also common types of descriptive research,[18] and one most people are familiar with in everyday life. For instance, Brown et al[19] surveyed a national sample of smokers in the UK to assess the public's awareness, beliefs, and usage of e-cigarettes. Zhou et al[20] evaluated awareness of mouth cancer in a survey of more than 3,000 members of the public. One last type of descriptive research is called a *retrospective chart review*, which relies on the analysis of already existing data, such as the analysis of existing health records.[21] Retrospective chart reviews work as major overviews of health data to identify patterns and trends over time and can be useful to give a first indication of an underlying health care issue (eg, if a mouth cancer diagnosis and history of tobacco use are noted as concurrently recorded for many patients [Fig 5]). For instance, in their retrospective chart review, Groome et al[22] observed a history of smoking more frequently recorded for patients with cancer of the anterior tongue.

Conclusion

Understanding the different aims and goals of the different types of quantitative research can help increase capacity and confidence in understanding, appraising, and applying quantitative evidence among health care students, professionals, and novice researchers in the quest for the provision of quality cancer care. The starting point is to differentiate between experimental and nonexperimental research. Experimental researchers take an active stance to test cause-and-effect relationships. Normally, what is tested is a new treatment or intervention. Experimental research aims to answer whether the hypothesis that the treatment works is true or not. To do so, it is key that any interference or noise or confounding is controlled, and true experimental research (as opposed to quasi-experimental research) is particularly effective in achieving this kind of control. Conversely, nonexperimental research can be pictured as one where the researcher is a passive agent; they do not manipulate variables or introduce interventions as they would do in an experiment. In nonexperimental research, researchers simply observe what happens naturally, and as such, they do not have complete control over it. Nonexperimental research can investigate several variables at the same time that can be used to anticipate outcomes. However, several confounding variables might remain uncontrolled, which dilutes the confidence one can place on the truthfulness of the relationship or association that is investigated. Therefore, such associations can only be tentative, and as such, they can never prove a causal link.

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